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ROYAL AERONAUTICAL SOCIETY

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Edited for the Council by J. LAURENCE PRITCHARD, Fellow

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NOTICES

Special General Meeting

A Special General Meeting of the Royal Aeronautical Society will be held, by order of the Council, on Monday, June 8th, 1925, at 5.15 p.m., in the Society's offices, 7, Albemarle Street, London, W.1, to consider a statement by the Chairman, and to consider the terms of a proposed amalgamation of the Institution of Aeronautical Engineers with the Royal Aeronautical Society.

Elections

The following members were elected at a Council Meeting held on May 12th:

Associate Fellows.—Mr. A. J. Hughes, O.B.E., and Flying Officer E. J. Kingston-McCloughry, D.S.O., D.F.C.

Associate Members.—Flying Officer R. Collins and Group Captain P. F. M. Fellowes, D.S.O.

The Air League of the British Empire

The following are the representatives of the Society on the Air League of the British Empire for the year ending April, 1926:—Lieutenant-Colonel Mervyn O'Gorman, C.B., D.Sc., Fellow, and Colonel The Master of Sempill, A.F.C., Associate Fellow.

Associate Fellowship Examination

Provided that sufficient entries are received, the Society's Examination for Associate Fellowship will be held on Monday, September 21st (Part I.), and Tuesday, September 22nd (Part II.). Entry forms may be obtained from the Honorary Secretary, and must be returned duly completed not later than Monday, August 24th.

Donations

The Council desire to thank the following donors:—Sir Mackenzie Chalmers for Part I., Volume 3, of the Journal of Comparative Legislation and International Law, containing an article on "Commercial Aviation Law," by A. W. Latey; and Professor G. H. Bryan for a case of pamphlets.

J. LAURENCE PRITCHARD,

Honorary Secretary.

XUM

PROCEEDINGS

TENTH MEETING, 60TH SESSION.

A meeting of the Society was held in the Library at 7, Albemarle Street, London, on Thursday, March 5th, 1925, Lieutenant-Colonel H. T. Tizard, Chairman of the Society, presiding.

SOME MEDICAL ASPECTS OF AIR TRANSPORT

BY C. B. HEALD, C.B.E., M.D., M.R.C.P., MEDICAL ADVISER TO DIRECTOR OF CIVIL AVIATION.

Introduction

Pilots, employers of pilots, insurance companies, the public, the medical profession, and the Government have undoubtedly a special interest in the medical questions of aviation.

I will therefore endeavour when dealing with the several heads into which I have divided my subject to keep the interests of each of these in view.

The medical work of civil aviation is not confined to the mere routine examination of pilots, although this naturally forms an important part of this work, but it finds also a useful field in matters concerning the general life of those associated with civil air transport, and in the general questions of hygiene and health organisation that help to build up comfortable and efficient services. I have in consequence divided my subject into the following three groups :—

1. The medical examination.
2. The life and work of the pilot.
3. Other aspects of medicine in relation to civil aviation.

I.—MEDICAL EXAMINATION

1 *The Pilot*

I am well aware that certain parts of the medical examination have frequently been criticised by pilots as having no bearing upon flying efficiency, and I must admit that, as seen by the layman, some of the tests may appear ridiculous. It will, I think, be interesting to explain in simple non-technical terms the reasons for the employment of these apparently stupid tests, and show that they are, in fact, closely correlated to efficiency in the air.

A pilot standing with hands extended, eyes shut, and tongue protruding, must look to you both undignified and ridiculous, but if I tell you that it is in this position that the early signs of inco-ordination and lack of nerve-muscle control show themselves, there is not a pilot who would not wish this test carried out, if only for his own protection.

When a pilot stands on one leg with eyes closed, he undergoes what is called the "balancing test," and a tremulous condition of the whole body is thought by some pilots to mean their probable rejection. No such thing! This unsteadiness is frequently found among the very best pilots, and is in my opinion of little or no significance. If, however, a pilot persistently falls to one side to such an extent that he either has to open his eyes or put his other leg down, it is of importance in relation to aviation, for it means that if he is unable to fix his position in space on account of his eyes being shut, he is likely to behave in a similar manner when flying in fog or clouds, etc. This loss of ability to

orientate is also an early symptom or sign of certain insidious diseases, and the very carrying out of the test is some protection to the pilot quite apart from its direct bearing upon flying.

The test known as the balancing rod test is carried out by a pilot lifting a small board with an unstable rod at the extreme end. Here again minor shakings are of no importance, but persistent lifting of the board is a clear indication that the co-ordination between hands and brain is imperfect, and when present to any great degree would be represented in flying by the pilot putting his machine at some other angle with the horizontal than his actual intention. It is obvious that errors of this kind might lead to a "stall," a bad "take-off" or a bad landing.

I now pass to three tests devised by that pioneer of air medicine, Group Captain M. Flack, and although they have not been criticised as ridiculous, they are, I am afraid, far from popular among pilots, as they involve a certain amount of personal discomfort. These tests are so well known that any detailed description as to how they are carried out is unnecessary, but briefly the reason for their use is to find out the condition of the expiratory muscles, the ability and probable reaction of the pilot when flying at great heights or for long periods. The important point to remember is, however, that these tests, unpleasant as they are to perform, have been conclusively proved by Flack's careful investigations to yield information of value, particularly as regards the onset of fatigue and other similar conditions.

These tests are the ones that have been the subject of comment, particularly by those who have been subjected to them, but there are of course other equally important tests, some of which I shall refer to later, but the pilot may rest assured that all the tests have some special significance. From the completed examination the pilot should secure the following definite advantages:—

1. Advice and guidance, enabling him to retain his fitness or regain it if it is deteriorating.
2. Early diagnosis of disease, when it is in its most preventable form.
3. A healthy knowledge of his own physical condition that should not only prolong his flying life, but keep him physiologically youthful.

The policy of the whole examination is rather well defined by Doctor Oliver Wendell Holmes in one of his verses on "The Wonderful One Hoss Shay," when he makes the deacon build a chaise equally sound in every part to last for a hundred years, for he recognises, in the following words, that an ordinary chaise does not wear out, but breaks down in some unsuspected part:—

"Now in building of chaises I tell you what,
There is always *somewhere* a weakest spot—
In hub, tyre, felloe, in spring or thill,
In panel, or crossbar, or floor, or sill,
In screw, bolt, thoroughbrace—lurking still,
Find it somewhere you must and will,
Above or below, or within or without,
And that's the reason, beyond a doubt,
A chaise *breaks down*, but doesn't *wear out*."

Therefore it must be our endeavour so to watch over the pilot that each weak spot is discovered in time.

2 *Administrative Aspects of the Medical Examination*

To the employers of pilots, especially those situated at considerable distances from London, the central medical examination seems perhaps to constitute unnecessary difficulties, and a brief examination of alternative methods, and a

statement of the advantages of a central examination, will show, I think, real justification for continuation, at any rate for the present, of the existing procedure.

If decentralisation were to be carried out, the medical examination would have to be done either by a doctor travelling continuously on behalf of the Air Ministry, or by selected and approved medical gentlemen at various centres.

The former method has been closely examined by the Air Ministry, and quite apart from the disadvantages of accommodation and equipment inherent in any such scheme, the movements of pilots and the different dates upon which their licences fall due would inevitably result in confusion.

The latter method, which has much to commend it, has, however, certain important disadvantages. There is the disadvantage of the moving pilot, the disadvantage of different medical methods, and, more important than either of these, the disadvantage that the examinations carried out at different centres would not be sufficient in number for the examining doctor to maintain a high standard of specialist skill.

The advantages of centralisation are considerable, and may be tabulated as follows :—

1. The accommodation can be adapted for the special needs of the examination.
2. The equipment and apparatus can be developed without considerations of portability and with the sole object of obtaining increased knowledge and a more accurate estimate of the physical condition of the examinee.
3. A system of graphical and other records can be maintained of a kind that would not be suitable for repeated circulation.
4. The same individual carrying out the examinations greatly enhances the value of the data obtained, and, by forming a bond of confidence with the pilot, knowledge is provided whether apparent abnormalities are of serious significance or not, and a safe elasticity is secured.

These are solid advantages, and though ultimately, with the growth of civil aviation, decentralisation will doubtless come, I cannot help hoping that it will not be before exact methods of medical examination have been devised so perfect that employers, insurance companies, and the public may know that wherever a pilot is examined and granted a " B " licence, he exhibits a high standard of physical efficiency.

It was no uncommon thing during the war to find that a pilot who had not been subjected to the special examination before acceptance had actually fainted in the air. To-day, however, as a result of the policy adopted by the Air Ministry, the possessors of " B " licences obtain certain special privileges from the insurance companies, and the public fly with complete confidence of the pilots' physical ability.

The preservation of this confidence is of the utmost importance. We do not want, and we cannot afford to have, sensational newspaper articles throwing doubt upon the physical condition of a commercial air pilot. Let us at all costs preserve our present claim " that there has never been yet any question as to the physical fitness of a civilian pilot holding a ' B ' licence."

3 *Technical Points of Interest in the Medical Examination*

The usual clinical procedure of any ordinary medical examination associated in the minds of the public with stethoscopes, saying " 99," and sundry tappings still forms an essential and valuable part of the examination, but there is one vital difference between the examination of a patient with symptoms and a healthy individual. In the former we are looking for the pathological causes

giving rise to the existing symptoms; in the latter we are endeavouring to estimate the degree of "wellness" of the examinee. Now since the regulations lay it down that every pilot shall be re-examined every six months, it is important that each successive record shall be capable of comparison with previous ones, and therefore any test that yields numerical or graphical data is of real value. These types of tests have therefore been considerably developed and now find a prominent place in the routine of the examination. The Flack tests previously referred to have an additional use on this account because when carried out by the same technique they give figures that can be compared from examination to examination.

Other tests yielding actual numerical data are the usual height, weight and chest and vision measurements, but apart from these I wish to draw special attention to a group of three numerical tests that together, I find, give me most useful information about the habits of a pilot as regards exercise and over-indulgence in food, drink, tobacco, etc. These "habit-detector" tests are:

1. The Exercise Tolerance Test.
2. The Blood Pressure Measurement.
3. The Vital Capacity Measurement.

Each of these tests may vary in different ways, and although the Royal Aeronautical Society is not the place to go into technical details of the significance of the combined variations, it is of interest to know that I find I can frequently attribute correctly the cause of any definite alteration to its true source, whether it be the "etcetera" or merely lack of exercise.

I feel also that I can sometimes actually name a popular Virginia cigarette as the cause of a certain type of physical condition developed by over-smoking, and I have often wondered whether the tobacco, paper, or other material in this cigarette may not have some minute quantity of toxic substance. Indeed, were my evidence of a more concrete nature, I should not hesitate to lay it before the Medical Research Council.

The medical examination thus becomes, as it were, divided into several parts, namely:—

That part assessing the basic physical standard of the pilot;
That part estimating the ability of the pilot in the air;
That part estimating the effect of the pilot's ground life on his basic physical condition,

and that part which, by making use of experience and clinical judgment, watches over and correlates all other parts. This last part is not, and never should, in the present state of our knowledge, be reducible to figures, but it is nevertheless an essential co-ordinating link.

When all these tests have been carried out one is left, not infrequently, with a double sense of dissatisfaction, one part tangible, and with which both the Royal Air Force Medical Services and civil aviation have attempted to deal —with some measure of success—and one less tangible, but the more important, about which I wish to speak at some length in the hope that I may obtain from the subsequent discussion inspiration and guidance.

Let me deal first with the more tangible kind of dissatisfaction that occurs to me when a pilot is exhibiting not signs of breakdown, but minor signals of change.

Take the simplest example. Acuity of hearing is tested by the whispered voice and by a variety of tuning forks. It is obvious that this method is but a rough guide, and is difficult to compare from examination to examination. Major W. S. Tucker, Head of the Acoustical Section of the Signals Experimental Establishment, Woolwich, found the same difficulty when selecting men for listening for the approach of aeroplanes, and in consequence he devised an

oscillating valve circuit similar to that used in "wireless" by connecting the grid of a valve (V) to an inductance (I_1). In the plate circuit of the valve is inserted a high tension battery (B), a second inductance (I_2) coupled with the first inductance a variable capacity (C), and a thermal milliameter (M). A circuit of this kind is an oscillating one, maintained by the reactance of the two coils (I_1 and I_2), and its frequency of oscillation can be varied by altering the capacity.

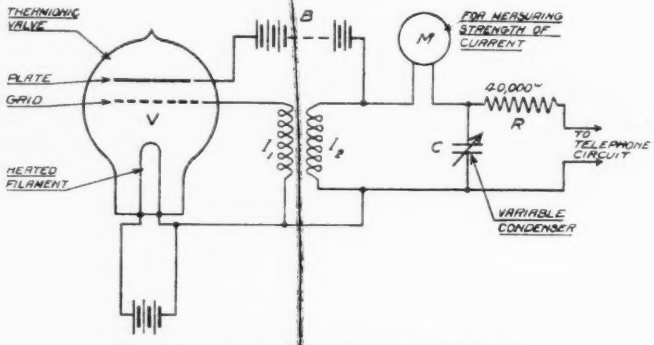


DIAGRAM OF APPARATUS FOR PRODUCING OSCILLATORY ELECTRIC CURRENTS OF DIFFERENT FREQUENCIES.

A range from 300 to several thousand oscillations per second can thus be reproduced as musical note of definite pitch. In order to make use of the circuit in this way the terminals of the variable condenser (C) are connected through a high resistance (r) to a bridge. The signal in the telephone on which the listener has to be tested can be weakened or strengthened by adjustment of the variable resistance (r) on the bridge, and a curve has been obtained showing the connection between the strength of signal and the value of the variable resistance. An apparatus of this kind is in practical use by Mr. Somerville Hastings at the Middlesex Hospital.

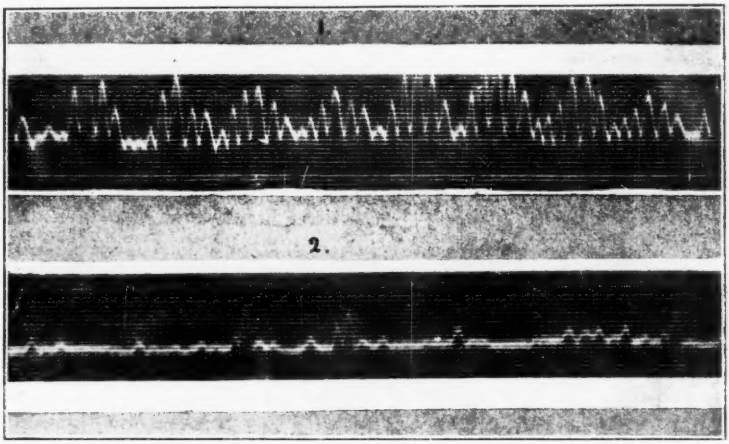
From the curve an arbitrary scale of power of audition can be drawn up and employed for classifying the subject under test.

This apparatus clearly provides more accurate data and also data that can be compared from examination to examination.

When examining the cardio-vascular system it not infrequently happens that although the numerical tests show little or no difference from previous examinations, one is left with the impression that this system is not quite normal and that some more accurate method is necessary to estimate whether the heart, etc., is to be relied upon to withstand the stress of long flights in bad weather. Unfortunately, the electro cardiograph is of little or no value for supplying this information. What is really required is an "indicator diagram" of the heart, this organ being regarded as the main engine of the pumping station.

Considerable progress has been made towards the solution of this problem, again with the help of Major Tucker, by devising an apparatus for recording the recoils of the body as a result of the contraction of the heart. This instrument is far from perfect, and much further work is required on the significance and interpretation of the curves obtained. The illustration shows two curves obtained from a pilot, the first being taken when his cardiac action was under suspicion, and the second two months later. It eventually transpired that this pilot had, on the first occasion, recently taken unnecessarily large quantities

of alcohol, and had, during the two months when he was deferred, reduced this intake to reasonable dimensions. I do not claim that these curves constitute a new test for drunkenness in the case of suspected motorists! But I show them merely to indicate the lines upon which we are endeavouring to work out improved methods for estimating physical efficiency.



The nervous system is another system about which we require further knowledge, particularly as regards its efficiency when acting as a whole. Recent researches carried out by Flight Lieutenant G. H. Reid, under the direction of Group Captain Flack, have made a great advance in helping us to assess the manner in which the delicate co-ordinated mechanism involved in actual flight is likely to function.

Through the kindness of Group Captain Flack I have been able to obtain three pairs of graphs which illustrate the difference found between highly efficient and inefficient pilots.

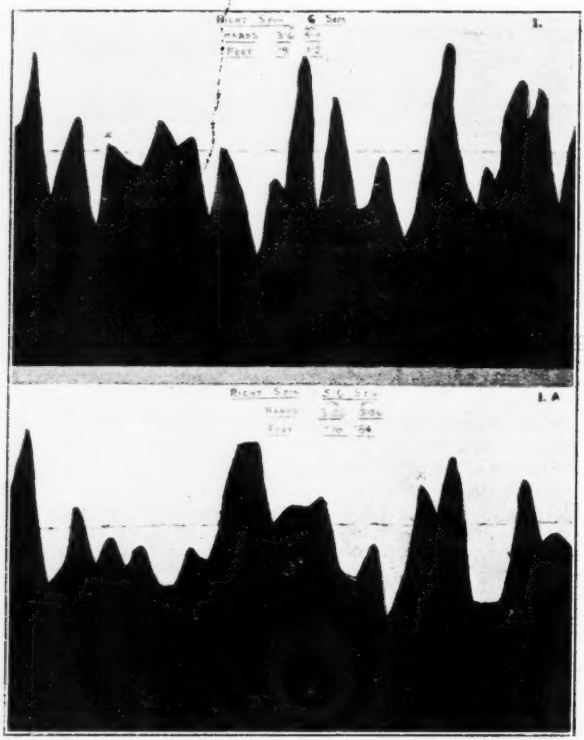
Graph I. was obtained from a pupil pilot before flying had actually commenced, and from past experience seemed to indicate that the individual would prove to have no aptitude for flying and be erratic in landing. Graph I.A is from the same individual nine months later, and this time the report was an administrative and not a medical one, and expressed the view "that after seventeen hours' dual he would never make an efficient pilot and had very little idea of landings."

The second pair of graphs are particularly interesting, as the subject, in this case a civil pilot, had suffered a severe injury on the ground resulting in partial paralysis of the right hand. The upper curve is from the left or uninjured side, and is the curve given by an average good pilot. The lower of the two curves is from the right side and is definitely more erratic and is of a higher value. Previously the curve from this side was worse by about eighteen per cent., the improvement being due to an energetic course of treatment by diathermy which I was able to give him because he had made no improvement for many months previously.

The third pair of graphs is also interesting, as the upper one is from an applicant for a civil licence who did not show up well in the medical examination and who was in consequence put through the test for additional information. His curve is again characteristic of a type which has no aptitude for flying—bad

hands, and hopeless at landings. The lower curve is from a famous civilian pilot who the Medical Research Department at Hampstead reports upon as "one of the best curves ever obtained and shows a remarkably good pilot with extraordinary quickness and co-ordination." I sincerely hope this special aptitude will assist us in regaining the Schneider Cup.

I think there can be no question that this apparatus has a considerable future before it in connection with air medicine, and I see no reason why modifications of it should not be used in many trades.

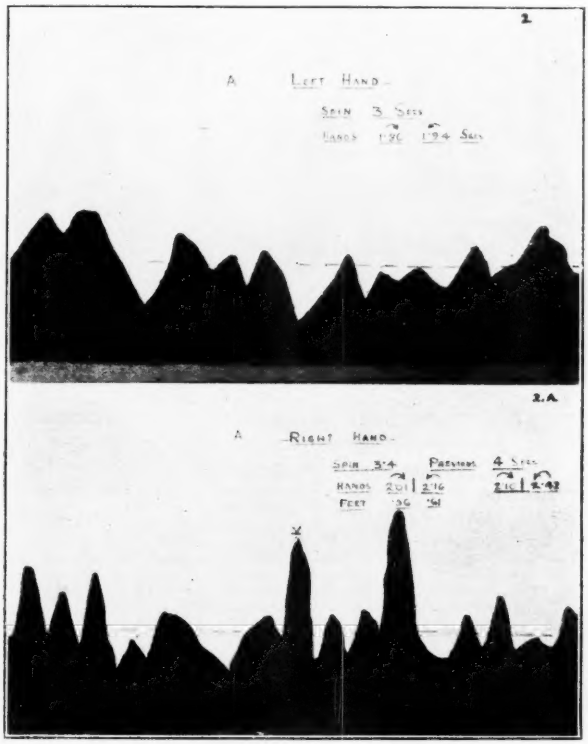


These three pieces of apparatus, namely, the Tucker Auditory Testing apparatus, the Heart Recoil apparatus, and the Reid Control apparatus, illustrate how air medicine is endeavouring to improve the technique of the examination, either by improved apparatus or by apparatus that yields information of more direct bearing on flying efficiency.

When all these tests are considered either separately or together, they function merely as a means for estimating either the presence of disease or the early signs of deterioration. In reality it is something quite different that is required, not merely for air medicine, but for the general health of the nation. We want to be able to estimate the existing condition of the systems for each particular individual and how these systems will last and will function under stress and strain for that individual—not for an average individual. Inspection, palpation, percussion, auscultation, useful as they are in clinical medicine and to-day in the examination of the pilot, yet they are crude and inadequate for the measurement

of physical condition as distinct from disease, and should be scrapped as soon as opportunity offers. Looking back over the progress of medicine during the last thirty years, is it not peculiarly suggestive as to where we should look for this new knowledge, for the outstanding features of progress have been chiefly electrical, *vide* radium, X-rays, ultra-violet rays, diathermy, etc.?

Now it does not seem to us in the least strange that these forces should have a profound influence on health and disease, however strange it seemed at the time of their discovery. I can well remember the time when men of considerable reputation were prepared to prove that flight in heavier-than-air machines was a



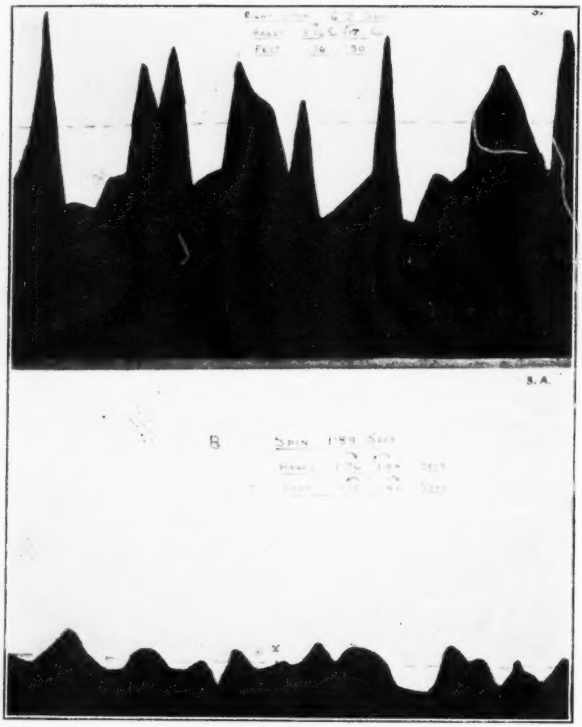
physical impossibility. I also remember the time when the worker who first described the causative organ of syphilis was told, through the medium of the medical journals, that what he saw was an artifact of his microscope! But the retarding effect on progress of this kind of criticism, though it may cause delay and do damage, is only temporary.

Despite the scoffers, there is a small band of workers, unfortunately reduced by the death of Sir James Mackenzie, who are widening our knowledge of the processes of life, and I cannot help feeling that the first real and tangible advance towards true estimation of physical efficiency will come, directly or indirectly, from our improving knowledge of electrical phenomena and the ultimate composition of matter. Now aviation has made great strides despite the sceptics and has drawn into its service men in the fore part of every branch of physical

science; moreover, it employs a uniquely fit body of men, under constant medical observation. And just as the pilots "climb the stair of the morning air," so must air medicine found and build, with the help of these technical experts, a newer medicine which will bring the country an improved measure of protection from disease.

For this reason, if for no other, research and investigation are and must remain a fundamental policy of the medical branch of the Department of Civil Aviation.

In order to put these beliefs in some small measure to practical tests, the



first tentative steps were taken some two or three years ago by instituting an investigation into certain claims that, if they proved capable of substantiation, would provide new avenues of information. Unfortunately, long after the investigation was well on its way the subject came under the ban of the orthodox medical profession.

There was much justification for this ban, and for the endeavours of the medical journals to place the absurd claims made by ignorant people in a true light. In this they have done, and are doing, a great service. It was not, however, any concern of air medicine whether disease could be diagnosed or located by this or that apparatus, but the immediate object of the investigation was to determine whether, hidden among the jargon and rubbish, there existed any physiological phenomenon that was new and that might ultimately prove of value.

The results of the preliminary investigation were communicated to the medical world in order merely to ask this question and to draw to our side physicists and medical men of wide knowledge and minds capable of receiving new ideas.

I shall greatly welcome in the subsequent discussion any views on the two following points:—

1. Is it right to go behind conventional methods of diagnosis of disease and to attempt to estimate physical efficiency as something connected with health rather than with disease, or are we for ever to stand by our stethoscopes and sphygmomanometers?
2. Is it to electricity that we should look for future developments, or is it, possibly, to some new force, as so strongly believed by the late Sir James Mackenzie?

II.—The Life and Work of the Pilot

It would indeed be a narrow-minded department that concerned itself only with the question of the fitness of the pilot at the moment when he presents himself for examination, and I therefore in this section propose to deal with those larger questions that influence or determine his health and durability, questions which are of particular moment to himself, to his employer and to the Government.

1 *The Pilot*

Much has already been written by medical men interested in the welfare of the pilot on such questions as the harm done by irregularity as regards hours of rest and feeding (*i.e.*, flying on an empty stomach), by insufficiency of regular exercise and by excessive use of tobacco and alcohol; and beyond re-emphasising their true and really great importance, I do not propose to go over the ground again, for it has never been controverted that for the pilot to retain his health and efficiency a life with steady habits is essential.

I have, however, this perfectly definite message to convey to the pilot, namely, that those who are abstemious in their habits and regular in their exercise show consistent clinical results in their examinations, and retain a constitution corresponding to an age lower than they actually are; while those who are less careful (and fortunately this is an increasingly small group) show irregular clinical results and a constitution belonging to men of much greater age. Now in this former group I have (at the special request of Air Vice-Marshal Sir Sefton Brancker) made careful observation of all pilots who have flown 250 hours in six months or less, and in those who do not suffer from apprehension I can find at present not the smallest trace of any physical deterioration, and those pilots (*i.e.*, the ones careful of their habits and condition) should be able to look forward to many years of such work.

This does not mean that I think the pilot will fly as efficiently at seventy years of age as he does to-day at thirty—he may, but much depends on the developments that take place in aviation *and* our knowledge of preventive medicine; on the contrary, I hold the view that every pilot should, if only during bad weather, begin to fit himself with a second string to his bow in the shape of some technical knowledge that may be put to profit on the ground.

In short, let the pilot keep himself in semi-training all the time, teach himself something technical other than mere piloting, and he need never be afraid of long hours of hard flying.

2 *The Employer*

I referred above to apprehension in the pilot. I do not wish it to be thought for a moment that I refer to anything akin to fear. I do not. The apprehension

to which I refer is altogether different and is a most important question and because it concerns (both as regards its production and its abolition) the employer and manufacturer more than the actual pilot I have included it in this section.

The apprehension of a pilot is an apprehension that arises sometimes on the question of whether he is secure in his employment or whether his basic salary is sufficient to keep him in comfort independent of good flying weather; or it may occur with lack of co-ordination or reliability of weather reports. Again, the presence or absence of apprehension depends upon the degree of confidence the management inspires, also on such questions as efficient wireless, good ground engineers, reliable engines, well-kept machines, and engines overhauled sufficiently often.

Apprehensions arising from any of these causes are legitimate apprehensions, and ones that employers and manufacturers can do much to reduce.

It is essential that the employer should recognise that apprehension can act subconsciously as well as consciously, and that when it is acting the physiological response of the individual is somewhat similar to a mixture of excessive exertion and a minor degree of shock.

The individual response naturally varies from pilot to pilot, but it takes the shape of increased muscle work of an unprofitable kind, increased nervous reflexes, acceleration of pulse and rise of blood pressure. I need not go into further details, but if such stimuli are constantly present in every flight, it is obvious that they must ultimately do harm in proportion to their number, extent and duration.

Every step taken to lessen or remove any of these apprehensions (probably especially the subconscious ones) is a step taken to increase confidence and automatically increase the flying life and efficiency of the pilot.

Every meteorological station that is always early or punctual with its weather reports and never adrift materially assists in implanting confidence in the pilot. Wireless that can be relied upon absolutely—that is indeed so reliable that the pilot does not switch on with a trace of doubt in his mind as to whether it will work or not—is of some real value. If, however, it is of the type that the pilot instinctively wonders whether it will function or not, then from the medical point of view it would be almost better for him to be independent of it.

So is it with each of the causes of apprehension referred to above—doubt of the ground engineer's reliability is bad for the pilot's health, confidence in him is good. The manager who makes a pilot take off from a " soft " aerodrome with a doubtful engine is undermining that pilot's health and is assisting in wearing out one of his most essential machines—the pilot himself.

The Reid control, if it could be made to function always and without fail, would help confidence, but in my opinion there is nothing so likely to be helpful in removing many of these apprehensions and inspiring confidence in trans-continental flying as the three-engined machine.

Important as these matters are from the mechanical, economical and reliability points of view, their medical aspects are even more important, because after all the pilot is the keystone of the whole structure.

The Rt. Hon. J. Whitley, before he became Speaker of the House, realised fully the medical aspects of many businesses and led him to say :—

> " If in their directorships or partnerships they had not sufficient human power to take their right share in this sort of work, it was time they set their own house in order, and brought in that human power, which would enable at least one of those acting as leaders in the factory, workshops, or industrial organisations to give his chief attention to the human side of industry, *and he would set up the human factor—the greatest factor in industry*—in a position not merely equal to the side

of commerce, finance, of science, of investigation and research, but give it first place "—

a statement that applies with peculiar force to aviation, aeroplanes or airships, especially in their development stages.

The pilot must also necessarily represent to the employer a potential source of income that becomes more valuable the more hours' flying he can be relied upon to carry out efficiently in the year. The employer does not wish either to endanger the reputation of his concern by sending pilots into the air in a physically exhausted condition or to shorten their useful flying life by overwork, as the value of experienced pilots will always remain very great; but he does desire to utilise him up to his full flying capacity and he will therefore look to the Air Ministry to tell him whether those pilots who in the summer have flown as much as 300 hours in three months have suffered thereby.

The answer cannot be given as a definite "Yes" or "No." It all depends firstly upon the type of pilot, namely, whether he is a highly-strung individual like most scout pilots, or whether he is of a phlegmatic habit; then on his basic physical condition, namely, whether his various systems are of sturdy stock or not; then on his habits as referred to above, also on the care taken to make his work on the ground easy and light, and to provide regular holidays right away from the tarmac and for opportunities for exercise.

Arising from this it is clear that the wise employer can do much to conserve the efficiency of his pilots, and I hold the view very strongly that the provision of ample opportunity for a "sweating" form of exercise on "dud" days and at night would do more to keep pilots fit than anything else. I have, beginning in 1916 and since then again and again, recommended that well-lighted squash racket courts with hot shower baths adjacent provide the most suitable and the most inexpensive form of exercise that can be carried out on "dud" days, and I again take the opportunity of re-emphasising this. I have also suggested that these courts might be built so that in time of emergency they could rapidly be converted into hangars or workshops.

There are two other points that appear to me to deserve the closer consideration of the designer, namely, the comfort of the pilot in the aeroplane and the desirability of a standard movement for all controls and a uniform position for the instruments.

As regards the former, it is obvious that when a pilot has to fly, perhaps, ten hours a day for several days together, his position, his protection and his comfort are of no small importance. I leave it at that.

The second point, that of standardisation of movements and position of instruments, etc., is far more important than would appear at first sight. It depends on this simple fact—that when any movement has been carried out many times it tends to become automatic, namely, to be carried out semi-subconsciously; indeed, almost as a reflex act. If later the individual acquires another movement for the same act, he will, in an emergency, tend to "regress," namely, to revert to the former act, and this has been the cause of many accidents in all kinds of occupations. The simplest example is the ordinary switch, which is usually down for "on" and up for "off"; it should never be reversed, however clearly marked.

The employer has, therefore, from the medical point of view, much that he can do to improve the efficiency of his organisation and the useful life of his pilots, in addition to the technical improvements in machines that are always taking place. He can study this question of apprehension in a sympathetic and constructive spirit. He can make opportunities for the technical training of his pilots in ground jobs. And he can consider the physical needs of his pilots, particularly as regards meals, exercise and holidays.

Government

The Air Ministry is also, of course, closely concerned with the pilot and with the employer, as to how he (the pilot) lives and the amount and type of work he is capable of carrying out. The civil pilot of to-day is a highly-skilled individual and constitutes first-class Reserve material, and as such should not be " used up " ruthlessly, but should be preserved as long as possible.

We have achieved to-day in Europe and further afield a reputation in civil aviation for skill second to none, and the public may like to know that the Director of Civil Aviation has given instructions to bring to his notice every case that has any bearing on the questions I have been discussing this afternoon, so that the type of physical characteristics that make the best pilot may be worked out.

The Air Ministry also recognises that it is only by the patient building up of records that we shall ultimately be able to give some idea of the useful flying life of the pilot.

It is also interested in the effect, if any, of long hours of flying, such as the trip of Mr. A. J. Cobham from London to Tangiers in thirteen hours, and closely associated with this comes the question of the physiological and clinical limits of speed and height. Both limits have been reached without artificial aid. Speed requires protection anywhere near two hundred miles an hour, and height requires the use of oxygen.

III.—Other Aspects of Medicine in Relation to Civil Aviation

The two previous sections have dealt at considerable length with the estimation of the physical condition of the pilot and with those factors of his life and work that have a bearing upon the successful development of civil aviation. In this section I propose to deal with what, for want of a better term, we may call the problems of flying that have a general medical bearing, such as ventilation, heating, etc.

1 *The Problems of the Passenger Car*

In aeroplanes, ventilation of the car is peculiarly difficult because, with the limited cubic space available for each passenger, if the air is changed sufficiently often to keep the carbon dioxide really low, a draught for someone is inevitable. If draughts are excluded the carbon dioxide content rises rapidly in so confined a space, also the air becomes " humanly contaminated," and unpleasant. It is, of course, impossible to give each passenger anything like the cubic space recommended even for crowded rooms, and estimations of carbon dioxide content are therefore useless, and we have, in consequence, adopted the Kata thermometer of Professor Leonard Hill as an altogether better means of measuring the condition of the air in the passenger car. This instrument is largely empirical, and gives readings from which practical information of value can be obtained as to the condition of the atmosphere. For Professor Hill has shown that it is this cooling effect that, more than anything else, determines the effect of a room, etc., on the human individual.

The best method of heating passenger cars has long been under consideration, and experiments are now in progress to determine as far as possible this point. Air mechanical questions arise in connection with it that necessitate a compromise, but the most hopeful experiments are those being carried out with a small high-pressure boiler worked by the exhaust gases, the superheated steam being carried in small protected pipes to radiators in the passenger car. Although this may not turn out as satisfactorily as hoped for, it is possible to state quite definitely that any heating of the passenger cars, either directly, with exhaust

gases, or with air that has been in contact with the exhaust pipes, is undesirable and unhealthy.

The problem of the satisfactory ventilation of the passenger cars in airships is somewhat different from that in aeroplanes, as the cubic space available for passengers is very much greater, and ventilation can be arranged on the principle that if air is sucked out, fresh air will always find its way in. This is the principle used in the American sleeping cars, and has been found to give great satisfaction when travelling at high speeds through very cold air. There are also, of course, many other medical questions that arise, and will arise, in connection with the development of airships, such as cooking, feeding, washing, sanitation, health of the crew and transport of disease, etc. These questions are receiving attention, but to go into any detail concerning them would unduly lengthen this paper.

Closely associated with ventilation and heating are the problems of the elimination of noise and vibration. These are important but far from simple problems; it is not merely a matter of reducing the sound of the explosion in the cylinders, for doing so, as has been found in aerial practice, may bring out a more unpleasant sound such as the screaming of the timing gears which the louder but more rounded sounds had hitherto blanketed. Vibration, especially when shut in in a closed cabin, may become fatiguing, and even act as one of the factors that bring on air sickness.

Air sickness, or the fear of air sickness, has deterred many hundreds from using the air regularly for transportation. It is, and has been, the worst advertising agent for civil aviation, far worse than the weather or possible danger, and the Air Ministry is keenly alive to the importance of obtaining some reliable means for reducing it to a minimum.

It cannot be simply solved by flying at considerable heights because there is still the individual who will suffer from nausea anywhere except on dry land! Drugs have been tried with some success, but not sufficiently to justify their introduction. Suggestions on this subject would be welcome provided they took the form of something a little more practical than that of one gentleman who asked permission to deal out "subtle soothing stomach strokings" to the passengers before embarking!

The subject is, however, of so much importance that a special committee of inquiry may be required, composed perhaps of designers, medico-physiologists and susceptible passengers.

I was particularly interested to read recently a report by Wing Commander Stedman upon his circular journey by European air routes, for in this he has much to say of real value upon the questions of comfort for the passenger. He draws attention to the unpleasant odour of staleness in the cabins of some machines, the exceedingly unpleasant effects of air sickness in badly-ventilated cabins and how these are exaggerated by journeys made during meal hours. He draws attention to the type of cabin that appears to give not only the best and most even ventilation, but the greatest freedom from air sickness, and his valuable observations and suggestions deserve serious attention, because in my opinion they contain, if not the whole solution of the difficulty of air sickness and ventilation, anyway a large advance towards that solution.

2 *Night Flying*

For successful night flying not only is it of the utmost importance to recognise that more than ever must any possible source of apprehension be removed, but it is also necessary to realise that for night flying the pilot wants specially selecting. The selection does not depend upon the night vision of the pilot, but upon the psychological suitability of the pilot for work of this kind. Then there

also arise questions of the most suitable lighting for the cockpit, and the angle required before objects can be distinguished. In one of the recent tests of night flying the pilot who completed these tests showed obvious signs that they had not been carried out without nervous strain. I am inclined to the view that the time for the inauguration of regular night services has not yet been reached, and that still further progress in the reliability of engines and in the perfection of automatic controls would be desirable.

3 *Medical Services*

Revised arrangements in connection with the main transcontinental air routes are in course of completion for first aid, both in the machine and at the ports of departure and arrival. In the machine, first-aid boxes conforming to an agreed international plan are to be carried by each passenger machine. The principles that have been agreed upon are that each box shall contain equipment sufficient for rendering first aid to two passengers, and that each machine shall carry sufficient boxes to render first aid to at least fifty per cent. of the maximum load of the aeroplane.

Both at Croydon and Lympne the first-aid services consist of a first-aid surgery and an ambulance.

Summary

I should like to take this opportunity of thanking my medical colleagues of the Royal Air Force, especially Air Commodore Munro, Group Captain Flack, and Wing Commanders Clements and Rippon for all the advice and willing help that they have given me since the beginning of civil aviation.

To summarise the advantages that appear to arise from continuity in medical control :—

The Government, through the Air Ministry, is able to watch the medical interests of the civil pilot, assist employers in securing the best physical type for endurance and skill, and protect the public from being carried by unhealthy or overworked individuals.

The Public realises that the disinterested official medical examination only passes individuals of high physical standard, and that from the point of view of the human element they can, and do, travel not only free from apprehension, but with a degree of confidence in their pilots equal to, if not higher than they could have in the pilots of any other nation.

The Employers, thanks to the skill and physical efficiency of their pilots, have improved chances in favour of a good record of safe flying, and thanks to this same physical efficiency know that they are more likely to obtain a remunerative amount of work out of their pilots for many years, as well as the best demonstration of their machines.

And the Pilot has confidence that by the early recognition of disease his useful flying life will undoubtedly be prolonged and his intimate relations with the medical branch of the Civil Aviation Department help him to carry out his duties more easily and more efficiently.

These indeed are solid and already established advantages that the medical profession may claim as their past and present contribution to civil aviation. Beyond these, however, I believe, as I indicated in Section I., that we are on the threshold of discovery of new methods in medicine.

In aviation, we are dealing for the first time so far as we know in the history of mankind, with life and work in the air, and we are learning facts about the mental and physical make-up of people that before were either unknown or only vaguely apprehended. It would surely, therefore, be a very fitting thing if, through this new science of aviation which has faced us with

new problems in the estimation of physical efficiency, we should find our feet set on a new pathway, leading possibly to a definite understanding of these forces that Sir Oliver Lodge, Professor Richet, and the late Sir James Mackenzie have already sensed.

I will venture for a moment into the realms of prophecy, and will say that I firmly believe that, in contrast to the diagnosis of already existing and established diseases, we shall before long find ourselves able to estimate the physical well-being of any individual, with a high degree of scientific accuracy; to forecast where his defences against possible disease are likely to prove weak, and, as forewarned is forearmed, thereby to increase his chances of a prolonged and healthy life, to the ultimate good not only of the one, but of the many—of the nation—of mankind—and we should spare no effort to capture these new positions.

NOTE.—A series of lantern slides, illustrating the various subjects dealt with by the lecturer, were shown in addition to the above diagrams.

DISCUSSION

Colonel TIZARD, in declaring the paper open for discussion, said that it was not often that laymen had an opportunity of meeting distinguished medical men on common ground in this way, and he hoped that the members would make good use of the opportunity. The work the lecturer had described went far beyond mere examination of pilots; it was really the beginning of a new era, for by trying to reduce to actual figures the results of their examinations they were taking part in the general movement of bringing medicine more into line with the exact sciences.

The greatest triumphs of medicine in the past had been in the prevention rather than the cure of disease, and the work they had been hearing about, directed as it was to the study of the healthy body, would be likely to lead in the end to very great advances in public health.

He would now make the kind of criticism of the paper that he was accustomed to in other branches of science. He thought that doctors claimed a little too much for their tests, and illustrated his meaning by an anecdote of Hendon days during the war. He had told no one of it at the time because the testing of pilots was only at the beginning and was to be encouraged rather than discouraged, and things had greatly improved since then. After a talk with the late Major Hopkinson, he decided to make a personal trial of the medical tests then being carried out. He took the opportunity of being examined after a tiring day in London by one doctor, who told him he ought to have a month's rest at once, and ought to give up flying entirely. He rested for half an hour, and was then examined independently by a second doctor, who passed him at once as a first-class scout pilot. Neither of these verdicts were accurate, in his opinion, which had always made him somewhat sceptical as to the accuracy of conclusions from a single series of medical tests.

He would have liked to hear a little more from the lecturer about the nervous mechanism, as he felt that there was a tendency to dogmatism on this question, which he had hoped the lecture would help to dissipate. The reason why he raised this point was because he had always understood that what might be called a "nervous individual" could not pass these tests as well as a man who was not of a nervous temperament. He might, however, pass them better, owing to the fact that his excitable nerves could string him up to a high pitch of efficiency for a short test. He would like to know what the experience of the lecturer was in this respect. Some of the very best pilots he knew during the war were of extremely nervous temperaments. One was still one of the best pilots, and another, whom he had never known to make a mistake in the air, was so nervous

before taking up a new machine for the first time that he could be seen to be trembling all over.

He thought there was much optimism about the methods described. On the basis of certain measurements, for instance, it is claimed that an accurate deduction can be made of a man's lung capacity. He had been tested by it, and the difference between the forecast and the actual measurement was over twenty per cent. Being interested in this subject, he had read the original papers on it very carefully, and noticed that the figures as to results obtained were given to four significant figures.

He hoped his remarks would not be taken in the wrong spirit, because he really regarded the work dealt with in the paper as extremely important, and considered that the results deserved very wide recognition indeed.

Major H. E. WIMPERIS said he had listened to the paper with very great interest indeed, because he thought advance in medical research was of first importance to the Royal Air Force and to civil aviation. He particularly welcomed the progress made in developing methods of numerical measurement which could be reduced to curves and diagrams, by means of which the purely personal impression made on the examiner by the pilot could be assisted. Such methods had been developed very largely through the energy of Group Captain Flack, who had kindly allowed the speaker to see the medical research laboratory at Hampstead, including the apparatus they had been shown on the screen.

There was one very important matter on which he would like information from the medical profession—what senses did the pilot use most: sight, sound or touch? Touch, of course, was used in regard to controls, sight in regard to instruments, sound in regard to the noise of the engine and to what was heard through the wireless telephone headpieces. He knew that the medical profession were very desirous that no more "gadgets" than was absolutely necessary should be fitted in the cockpit for the pilot to watch. He hoped also that it might be possible to limit their growth; but taking, for instance, the research that had recently been made in regard to a stall indicator, one could not deny that such a device might be extremely useful, and there would be successors. But did the medical profession consider that the stalling signal should be given to the pilot by means of sight or sound? Which of the senses at present used by the pilot could best take up the additional load?

Lieutenant-Colonel I. A. E. EDWARDS said that before he had read the paper he thought the lecture would probably be a very dull one because the subject was a very difficult one to make interesting. He had, however, found the paper on the contrary to be one of the most interesting he had read for a long time; it was full of practical facts which were of extreme value both to military and civil aviation. The lecturer very rightly showed that the keystone of the aeronautical edifice was the pilot. He agreed strongly with him on this. It did not matter what advances were made in machine design, technical development, etc., they would still not achieve perfection without good pilots. They now knew that proper selection of these was being carried out, and so far as the medical part was concerned further researches towards maintaining their fitness were being made.

The question of whether sight or sound was the most desirable sense to use in regard to instruments was particularly interesting to his department, as it was at the moment getting out some specifications for instruments giving a sight warning and not a sound one. If they were wrong it would be a great pity.

He congratulated the lecturer on his excellent paper.

Sir THOMAS HORDER did not dispute the fact that medicine was a very inexact science. He congratulated the lecturer on the extremely lucid way in which he had summarised the history of the application of medicine to aeronautics and

particularly to the pilot. The note of prophecy that there would be a great deal of benefit accruing to medicine in the experience gained in the examination of pilots was fully justified in his opinion. It was by the constant association of medicine with physical, chemical and other developments of the more exact sciences that medicine might hope in the remote future to get rid of the stigma to which speakers in the discussion had made reference. To replace "impressions" by instruments of precision was what all thinking medical men were aiming at, both in diagnosis and in treatment. The great value of the work referred to this evening lay in this fact.

The Chairman's reasoning as regarded his two examinations at Hendon was not without fallacy regarded as a scientific experiment.

A very important sense to the pilot was the muscular sense, with which was closely associated the sense of equilibrium. Medical men were still uncertain how much of muscular balance is contributed by the actual muscles, and how much is contributed by that extremely important but minute piece of mechanism, the labyrinthine canals. He went so far as to say that they did not yet possess a very exact knowledge of this question. It was a branch of physiology requiring more exploration. Of its great importance in life generally, and to the pilot particularly, there could be no question. No doubt medicine would gain here, as in other fields, by the studies and experiments now being made by medical men, whose work brought them into contact with prospective pilots.

Wing Commander T. R. CAVE-BROWNE-CAVE said that the really adequate warming of crew and passengers was a factor of first-class importance, and considerable work was being done on this problem in connection with the new airship R.101. The heat which was necessarily discharged from the engine jackets at present involved large radiators causing much head resistance. It was sufficient, if it could be conveyed to the passenger and crew spaces, to produce a really comfortable temperature in a very generous ventilation.

The only way of conveying this large quantity of heat without involving considerable weight was to use steam. The economical way of making the steam was, he thought, not as Colonel Heald suggested in a special exhaust boiler, but in the jackets of the engine itself, if the water circulation system could be so re-arranged as to render this satisfactory.

Considerable success with this evaporative cooling system had already been attained with an airship engine. As a result of this experience he strongly recommended that a similar attempt should be made with ordinary aeroplane engines, because the value of this supply of heat and ventilation to the cabins of the aeroplane would go so far to overcome personal discomfort which Colonel Heald had referred to as the most serious factor against the popularity of air travel.

Would Colonel Heald say what would be the effect on the endurance and general efficiency of the pilot and crew of keeping them at the optimum temperature? Also would it be necessary to increase the humidity of air taken in at considerable altitude and warmed before being supplied to the passenger cabin?

Group Captain MARTIN FLACK congratulated the lecturer on the breadth of his survey.

One point which he wished to make was that the standard of medical fitness for pilots had been made by the executive and airmen themselves, not by the medical profession. He meant that the standard in the tests described by the lecturer had been ascertained by testing pilots selected by the executive, constituting a definite control examination. It had been shown that these did enable a classification of pilots to be made that could be thoroughly depended upon. He gave statistics that had been worked out which proved this most clearly.

He also drew attention to the great importance of the sense of vision to pilots, then came the sense of deep muscular control, the other senses playing a very little part. So important was the sense of vision that more care should be made to group the instruments on the dashboard of the cockpit in what was known as cone vision. Where signals were required to be given, as for example with a " stalling " indicator, they should be given by a light that could be easily perceived by peripheral vision, in whatever position the pilot might find himself. It would, in his opinion, be a serious mistake ever to use a sound signal.

In night flying or in fog no instrument would be of the same value where light was not employed. If the pilot had to read anything from a dial he would have to use limited central vision, and therefore he must have anything in the nature of an emergency signal so that it came in from the periphery, if it was to be effective.

With regard to the importance to pilots of the labyrinthine canals, he was of opinion that except for the part they played in neuro-muscular co-ordination, they were not of particular importance in flying.

Flight Lieutenant REID said that he had been working in conjunction with the Medical Research Department for the last twelve months, and had acquired a good insight into the medical methods adopted. The methods were practically the same as in any other well-conducted research in other branches of science. A number of subjects would be examined, and their characteristics obtained. Those characteristics would then be classified according to the known history of the subjects, and when certain types of characteristics were common, these were noted. If one failure was found, then deductions would be made to ascertain the cause of that failure. Undoubtedly a great deal of the success at present attending the design of modern instruments for flying was due to the co-operation of the medical profession and the technical and flying personnel. Questions of illumination, visibility of instruments, means of indicating, all requiring, as they do, knowledge of the functioning of the eyes in conjunction with the brain and muscle, must for efficiency be first referred to the medical experts. If this close co-operation was continued, undoubtedly perfection would be arrived at. Regarding the question of ventilation of aircraft, a slide had been shown of an American machine, in which holes had been made for the air to be sucked out. It was quite as likely to be sucked in, or inoperative. A method worth trying would perhaps be a system of " venturi " ventilation, so that air could be sucked out from any odd corner of the cabin, difficult to get at by any other means.

Mr. W. P. SAVAGE said that the problem of efficiently heating and ventilating the cabin of a passenger aircraft had not yet been met, and he agreed with the lecturer with regard to the atmosphere existing after two or three hours in the air in a full cabin, when it was almost impossible to feel well.

The medium had not been struck between partial suffocation and hundred miles an hour draughts.

Experiment must continue on this very important side of commercial aviation, for it must be remembered that as longer journeys are made, the same machine will be required to fly through atmospheres of extreme temperatures.

The American method of ventilating trains as suggested by the lecturer had been applied to aircraft, but it did not meet the case—at all events on the machine he had in mind. Not only was there no outward air flow through the ventilators, which were fitted at the back of the cabin, but there was an inward flow which brought in rain, cloud, and even snow, and all movement of air along the cabin was from back to front. This was caused by the greater suction out of the pilot's cockpit, which was in the nose of the machine, there being a communicating gangway with doors between the cockpit and the cabin.

He had hopes of a scheme which utilised cowls to force air along the hollow

rails of the luggage racks and thence into the cabin through diffusion holes being more successful.

He would ask the lecturer if there was a minimum volume of air space that appeared desirable from the medical point of view.

It had been suggested that cabins should be heated by means of steam from the water jackets of the engines, but he would ask how it was proposed to produce the steam when the machine had air-cooled engines fitted. It would appear to be necessary to carry a special boiler in such a case.

Would not a small electric radiator be better, with the necessary precautions taken against fire?

He would ask the lecturer what was the effect of noise on the nervous system of pilot and passengers, and whether it had any bearing on the question of air-sickness.

Multiplicity of instruments on the pilot's dashboard requiring his attention has been enlarged upon. The cockpit of a commercial machine could scarcely be compared to that of some types of Service machines in regard to this point, and if it were difficult for the commercial pilot to cope with his, what was the position of the Service pilot, as he obviously had much more to occupy his mind?

In conclusion, he would like to add to those already expressed his congratulations to Colonel Heald for his extremely interesting lecture.

Reply by DR. C. B. HEALD.

May I thank you for the very kind reception you have given the paper, and for the many interesting points raised in the discussion. I will endeavour to deal with these as briefly as possible, but in doing so I do not wish to indicate that I do not think them of great importance. On the contrary, I have received much food for thought, to say nothing of the encouragement given by the attitude taken up in the discussion both by the medical and lay speakers.

The Chairman quite correctly drew attention to the fact that measurements taken from human beings of vital capacity, etc., did not lend themselves to such accuracy as appeared to be claimed for them in Professor Dreyer's book. Actually, the great majority of civil pilots showed at least twenty per cent. above the normal for Dreyer's Class I. individual. The Chairman's reference to the highly-strung or "nervous" individual is one with which all medical officers are greatly in sympathy. And it is here that personal knowledge of the individual becomes of such great importance.

Major Wimperis raised one important point which was also referred to by other speakers. He asked: "Did the medical profession consider that the stalling signal should be given to the pilot by means of sight or sound, and which of the senses at present used by the pilot could best take up the additional load?" Group Captain Flack stated extremely clearly his reasoned physiological views on this question. I venture to take a different view altogether, and suggest that neither sight nor sound should be used and that some part of the sensory system, having no load upon it, should be made use of for providing a stalling signal. It seems to me that this could be done extremely easily, and graduated as the stalling point approached, by providing the pilot on his "Joy Stick" arm with a wristlet to which a small induced current (called in medical circles a faradic current) could be conveyed. This would provide something entirely distinctive in the way of stimulus, and tend to improve the speed of movement of the actual muscles required to prevent the stalling.

I was extremely glad to hear Colonel Edwards emphasise his view, which should be the view of everyone, that the pilot is the actual keystone.

The presence of Sir Thomas Horder here to-day shows that the skilled physician not only recognises, but is in sympathy with, all questions dealing with

physical efficiency as distinct from the recognition of disease. Indeed, I suspect that he would be the first to admit that his present great reputation is largely based upon an instinctive recognition of the basic physical make-up of his patients combined with a perfectly open mind until he has accumulated his facts.

Wing Commander Cave-Browne-Cave raised two important questions—one, when he asked: "Was it of importance to keep the pilot warm?" The answer is unquestionably and undoubtedly "Yes." His second question, "Ought the air in cabins to be kept humid?" is one that I cannot answer, but will make a special point of looking into.

Group Captain Flack's remarks deserve the close attention of everyone interested in the medical fitness of pilots, particularly when he emphasises the fact that the pilots have set their own standard of fitness.

Flight Lieutenant Reid made some complimentary remarks about working with the medical profession. I should like to return the compliment by saying that his ready and sympathetic reception of ideas makes him a peculiarly easy person to work with.

Mr. Savage's remarks require close and careful consideration, as they raise points of interest and importance.

Wing Commander Rippon's remarks, seeing that he has experience of both civil and Service pilots, require careful attention, not only on this account, but because he brings to these questions always a stimulating and refreshing method of considering them.

As I said during the course of my lecture, Air Commodore Munro greatly regretted that owing to indisposition he was unable to take part in the discussion, and desired me to say that he would have raised two points—the first that he considers decentralisation will probably come earlier than I have forecast, and secondly that he is entirely in sympathy with all efforts to improve our knowledge of basic physical efficiency.

Regarding the question of decentralisation, I am entirely in agreement with Air Commodore Munro that this will have to come sooner or later, and I think there will be little or no harm from such decentralisation provided it left the Air Ministry a sufficient number of pilots, particularly those employed on the strenuous work of trans-continental flying, to carry on with the investigation of those questions of basic physical efficiency to which I have already referred.

I thank you, Mr. Chairman.

Colonel TIZARD, in proposing a very hearty vote of thanks for a most interesting paper, said that he hoped that the public would get to know more of this work, which was not only of great importance for the future of aviation, but also in connection with wider questions of public health.

Wing Commander T. S. RIPPON (*communicated*): Our investigations have shown that flying is within the scope of the majority of young healthy adults.

We have observed, however, that in common with motor-car and tram-car drivers, there are some individuals who seldom or never have accidents due to errors of judgment, and others who frequently have them.

As the result of a large number of examinations on aviators, we can classify them into three classes, viz.:—

The Average Aviator.
The Super Aviator.
The Crasher.

The Average Aviator. In my opinion all normal adults under 45 who have not lived a purely sedentary life and strained their eyes by close work, and are not unusually nervous, should succeed in becoming Average Aviators.

The Super Aviators are individuals possessed with what is popularly known

as the "flying temperament." They have good "hands," their reflexes are rapid and accurate, they have a sort of instinctive foresight, and an alert and comprehensive power of attention.

The "Crasher" Class. The following can be detected by the medical examination:—

(1) The erratic lander suffering from defective vision.
(2) The individual who faints at altitudes.
(3) Those who get dizzy and lose control in a spin.
(4) Dimness of vision at night.
(5) Inability to stand fatigue.

There are certain disabilities which are associated with what is called "Lack of aptitude for flying" (such as lack of foresight, poor observation, mental sluggishness, poor muscular and joint sense, etc., associated with heavy-handedness on the controls), which may be detected by suitable mental tests, but it has been thought that "aptitude" is not a medical subject, but rather is the prerogative of the flying instructor.

I believe that we can provide vocational tests on the lines of Reid's control indicator test combined with mental tests, which may be helpful in selecting individuals for certain types of aircraft, and so on, but these should only be used in conjunction with actual flying tests.

These tests have a similar bearing to aptitude for flying as wind tunnel tests have to the performance of aeroplanes.

Errors of Judgment and Fatigue.—Recently-published statistics show that nearly all flying accidents are due to errors of judgment.

Definition.—An error of judgment is defined as a failure to make the correct movement (or combination of movements) when in a predicament or accident situation.

Correct Flying.—Ability to make the correct movement in an accident situation depends on:—

1. Knowledge of what to do (*i.e.*, the pilot has been well trained and is experienced).
2. He remembers the correct movements.
3. He appreciates the accident situation fully and quickly.
4. He does not get flustered or lose his head.

Now why does an experienced pilot make an error of judgment, such as a stall or a bad landing? And why does a novice, on his first solo, so frequently make an error on landing?

In my opinion the cause in most cases is mental fatigue.

For example, take the novice. Flying is not yet automatic. He has *consciously* to do over half a dozen things at once. The mind is fatigued by the effort to keep the attention fixed on *all* the manipulative movements necessary in the effort to keep from swinging, to land into wind, to keep up flying speed, etc., and a time comes when the attention is fatigued, and there is a lag or delay in the perception of the nearness of the ground. On the other hand, if he concentrates on the ground, he may forget something else.

In the case of experienced pilots I speak with diffidence. I will ask those of you who are experienced pilots to ponder the following facts:—

1. Last year, Griffiths, after an altitude test, stalled on a turn when about to land. His skill as a pilot was unquestioned. There was no defect in the aeroplane, and the oxygen apparatus was working properly. The accident was due to an error of judgment after an exceptionally tiring flight.

2. In the R.A.F. (I speak on the authority of an ex-C.F.S. Chief Instructor) the landings of a formation after a long patrol are often noticed to be not so good as those done when they are fresh.

3. *Industrial Accidents.* In factories, accidents show a definite ratio to fatigue. In the Manchester cotton industry the accidents in the early morning are few, and gradually increase until just before the dinner hour; there is a drop again after the rest period, and another rise during the afternoon.

4. There are psychological tests for attention (*e.g.*, the dotting test) which you can try yourself and see that as your attention is fatigued, so you make mistakes.

Moral.—If you accept the inference that accidents and fatigue are associated, what is the moral?

1. Do not increase the number of gadgets on an aeroplane beyond the capacity of the attention of the pilot.

2. Mental fatigue has a definite ratio to physical fatigue. You cannot think quickly if you have not a good circulation of well-oxygenated blood in the brain. Physical fitness is essential.

3. *A Stalling Signal.* This suggestion was first made to me by Captain De Havilland. The idea is simple. The speed indicator is fitted with an electric lamp which is automatically switched on when the aeroplane begins to lose flying speed, but before the stalling point occurs. I have two observations to make on this idea. (1) Pilots are taught to fly by the feel of the controls; they are trained to rely on this to recognise stalling point. A tired man tends to be slow in responding to the message which the sense of touch sends to his brain; he needs a danger signal of a striking nature. (2) It was suggested that the signal should be a red electric light. It seems to me that this is not striking enough. The noise of the engine is a bar to sound signals, and the third alternative that occurs to me is a galvanic shock signal which has obvious disadvantages.

I strongly recommend Captain De Havilland's stalling signal idea, and I feel sure that a few experiments will indicate the most suitable type of signal.

In conclusion, may I refer to the question of the *standard of fitness* necessary.

We have been adversely criticised at times because we have refused to certify as fit certain pilots of well-known skill.

May I explain that our meaning of "fitness" as applied to the pilot of a passenger-carrying aeroplane (or in the R.A.F. to an officer who may be ordered at any time to fly) is that there is sufficient stamina or reserve of strength present so that he could stand a prolonged flight with exposure to cold and high altitudes without the risk of deterioration in flying due to fatigue.

Our standardised tests show up the *early* signs of fatigue before the individual may be conscious himself of it. As long as a commercial aeroplane can be crashed through an error of judgment of the pilot, so must the standard of fitness be high.

PROCEEDINGS

SEVENTH MEETING, SECOND HALF, 60TH SESSION.

A well-attended meeting of the Royal Aeronautical Society was held in the lecture theatre of the Royal Society of Arts, 18, John Street, Adelphi, London, W.C.2, on Thursday, March 26th, when Dr. Eckener (Chairman of the Zeppelin Co.) read a paper on "Modern Zeppelin Airships." Colonel H. T. Tizard (Chairman of the Society) presided.

The CHAIRMAN, introducing Dr. Eckener, said he would be well known to those present as the present Chairman of the Zeppelin Co. He first came into association with Count Zeppelin twenty-five years ago, and for some eight or ten years before the war was actively engaged in furthering the commercial use of lighter-than-air craft. During the war he had trained all the pilots for the Zeppelin ships. Since the war he had been actively engaged in developing still further the commercial operation of these ships, and had been very closely concerned with recent developments in America. He was probably best known, however, for his magnificent performance in piloting the Z.R.III. to America. Dr. Eckener was naturally anxious to further in any way possible the development of rigid airships in every part of the world. He had made personally over 2,000 separate flights in rigid airships, which would be equivalent to at least 6,000 hours in the air.

Dr. ECKENER then read his paper, as follows:—

MODERN ZEPPELIN AIRSHIPS

LADIES AND GENTLEMEN,

It is no doubt known to you that when Count Zeppelin, at the end of the last century, began to realise his plan to build a rigid airship of gigantic dimensions, he encountered much doubt and contradiction. It was generally believed that such an airship would be too fragile to stay aloft in stormy weather, and especially to land without taking damage. But undaunted by these doubts and undeterred by incipial mishaps, Count Zeppelin attempted with the greatest tenacity to carry out his idea, until at length he was able to show results that seemed to vindicate his faith.

However, when he achieved these successes around the year 1906, it was shown that the light motors which had made them possible, had also brought the possibility of air navigation with heavier-than-air machines. And now those voices which announced that the future would very soon belong not to the airships because of their tremendous size, but to the airplanes which would be developed to an undreamed-of degree, became more and more audible and insistent.

This opinion is still to-day the conviction of wide circles, especially among the technically trained. Yet it is noteworthy that the lighter-than-air craft was not, as the friends of the airplane had prophesied, discarded, but that it, too, proceeded to undergo such an astonishing development that it was able to maintain itself alongside the airplane. This was due to the fact that the airship has certain qualities that in some respects give it a superiority over the airplane; it can cover much greater distances than the airplane; it can reduce its speed to nil and still remain in the air; it can travel and land in fog, snowstorm and night much more securely than the airplane. Personally, I am of the opinion that it is much easier to keep the airship aloft in stormy weather than is the case with the airplane. During the Great War the development of aviation made tremendous strides. The achievements of the airplane as regards speed, ascending power, etc., were doubled and tripled and its safety was developed almost to

perfection. But, as every expert in aeronautics knows, the capabilities of the airship underwent an equally successful development. Thus it was possible for us after the war, on the basis of our wartime experiences, to build a small airship, called the "Bodensee," and to inaugurate with it in 1919 a regular air traffic between Friedrichshafen and Berlin which, according to the judgment of impartial experts, was the best and promptest known anywhere at that time. During the succeeding years airship construction remained at a standstill in Germany and only airplane traffic could be further developed.

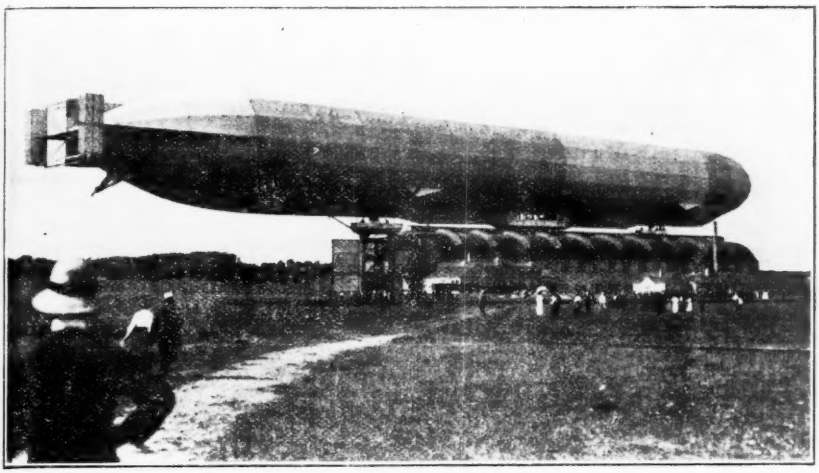
However, when after five years of enforced idleness the order for Z.R.III. gave us the chance to show the capabilities of a modern airship, we were able to prove through our trip to the United States that the airship is in certain respects even to-day quite as superior to the airplane as it was twenty years ago. It is possible that within a few years airplanes will also be able to travel safely to America. But is not the question justified what the airship will be able to do by that time, provided that the work of developing it is steadfastly pursued.

Permit me to give you a brief outline of the evolution of the Zeppelin airship up to date.

This evolution revolves in the main around two points: Firstly, speed; and secondly, relative carrying power. Relative carrying power means, of course, the commercial carrying capacity by percentage with a given size of the ship and provided that the ships are of an equal stability. As for the development of the speed which enabled the airships to conquer strong winds and even storms, you are no doubt familiar with the decisive part that the development of the motor has played in this respect. Suffice it to point to the fact that Count Zeppelin had in his first airship, in 1900, a motor of 15 h.p., which weighed 480 kg. (1,060 lbs.); that in his second airship, in 1905, he had a motor of 80 h.p., also weighing 480 kg. (1,060 lbs.); and that the last motors during the war were 260 h.p. with almost exactly the same weight.

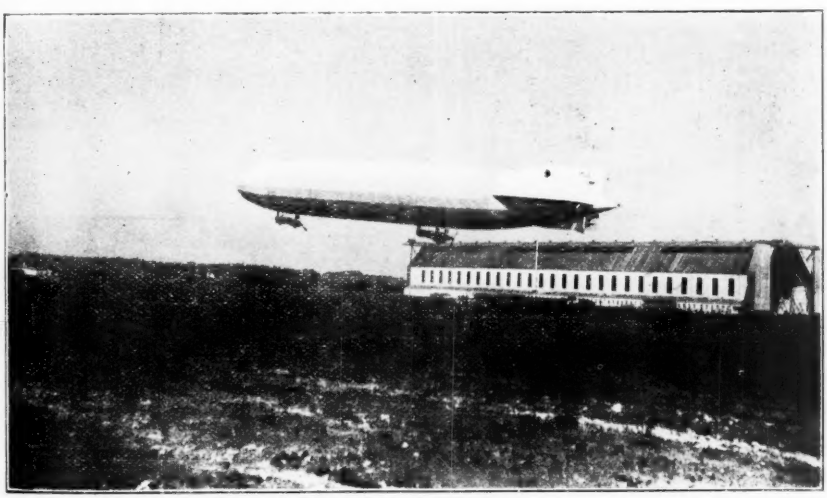
Still more interesting is the gradual increase of the airship speed brought about by an improvement in the shape of the vessel, reduction of incidental resistance and of the surface friction and such like. What a primitive impression one gets in looking to-day at pictures of the first ships with regard to these important factors; we cannot help but smile at those unwieldy bags. They had an outright cylinder shape with rather full ends—a shape which has no regard for streamline form; gondolas and engines are apparently constructed without taking into account the various factors of resistance, and as for the steering apparatus, their constructors seem to have been utterly at a loss to give them proper adjustment or proper place. I need not discourse in detail upon these first types and their development which to-day are merely of an historical interest; I shall show you afterwards a few pictures that will give you an idea of the Zeppelin airship in its infancy.

If we wish to understand the apparent primitiveness of the first types, we must remember that in those days the builders could take into account only the weight of the hull, the ship's carrying capacity, and the greatest possible simplicity of construction. Hence the choice of the simple cylinder shape with baggy ends. Moreover, the weight of the motors was still so great that one could figure only upon a moderate speed; the resistance did not play nearly as far-reaching a part as it does to-day. The full form of the stern, which with the first comparatively small ships (they only had from 11,000 to 15,000 cbm.—12 to 16 tons) was dictated by reasons of carrying capacity, subsequently resulted in new disadvantages. For, owing to this shape, there was no air current at the stern, but on the contrary there was a suction, and as a consequence steering rudders were ineffective within the scope of this suction. So they constructed a large square steering frame in order to place the rudders as far as possible out into the fresh air current. This partly accounts for the strange forms of the first ships.



L.Z. 10, Schwaben.

The speed attained by those types up to the time of the beginning of the war amounted at the most to about 18 m.s. (35 kts.) and the relative commercial carrying lift was about 25 per cent. of the total lift. When you consider that the Z.R.III. has a speed of 36 m.s. (70 kts.) with a useful lift of 56 per cent. of the total lift, the immense progress made since those Zeppelin pioneers is evident. This progress is even more clearly demonstrated by the fact that Z.R.III., a ship of 70,000 cbm. (75 tons), with an engine capacity of only 400 h.p.

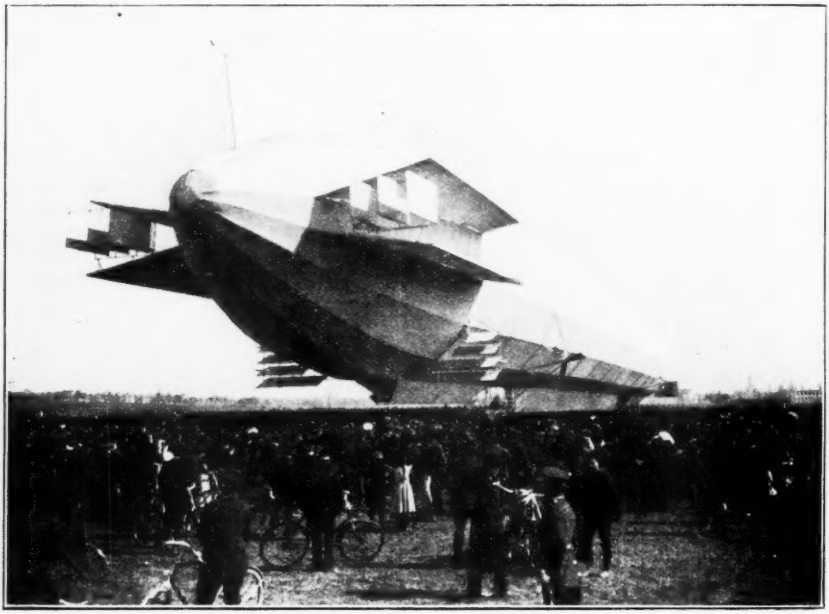


L.Z. 41. L. 11.
Note gun platform on top and airscrews on gantries abreast after car.

would have the same speed as the last pre-war airship of 18,000 cbm. (19.4 tons) with 500 h.p., namely, 18 m.s. (35 kts.), and that under this hypothesis its relative capacity would be 65 per cent. as against 25 per cent. of the last pre-war ship.

Five of the airships built before the war were constructed for passenger traffic. It goes without saying that owing to their small speed—about 35 kts.—these ships were not suited for carrying out regular air traffic. They were used, therefore, chiefly for round trips and only occasionally for fixed routes, and meanwhile constant efforts were made to improve the ships and to develop the art of handling them. But after all, it is a noteworthy fact that upon these trips, which numbered more than 2,000, a total of 42,000 occupants were carried without a mishap to a single passenger.

The systematic development of the Zeppelin airship along more scientific lines, with a view to attaining the greatest possible capabilities, began shortly before the outbreak of the war and proceeded during the war with amazing

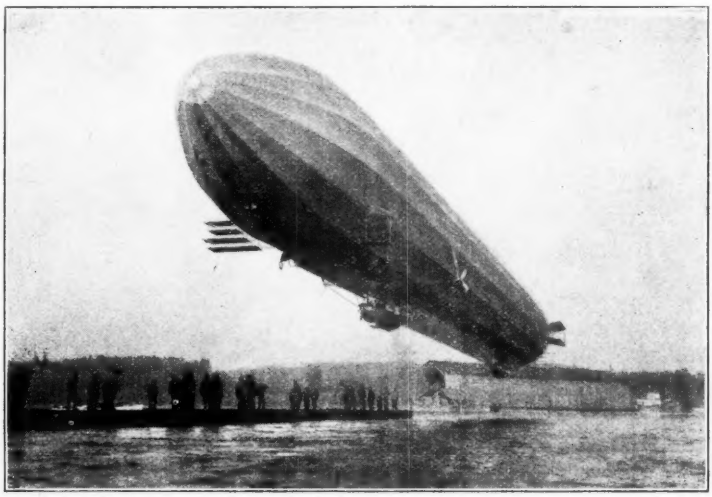


L.Z. 3.

rapidity. Since in the enlargement of the ship's size the required construction weights do not increase in the same measure as the contents, it is obvious that building larger ships offered the chance for an increase of its capabilities. Taking account of the military requirements for greater speed and greater ascending power to a maximum height, the size quickly grew from a good 20,000 cbm. (21.6 tons) at the beginning of the war to a 32,000 and 36,000 cbm. (35 to 39 tons) in 1915, to 56,000 cbm. (60 tons) in 1916, and finally to almost 70,000 cbm. (75 tons) in 1918. Meanwhile there ran parallel with this development of speed an improvement of the shape, which became more and more feasible with the increasing size. This improvement affected not only the ship's body itself but primarily also the gondolas as well as the ship's

entire organism. At the same time the constructors also were busily engaged in the work of removing or reducing all incidental resistance. Thus was gradually developed the so-called streamline form—a compact, smooth, cigar-shaped bag, in the construction of which special pains were taken to avoid as much as possible all outstanding wirework or other impeding objects protruding from the surface of the vessel.

While the improvements I have spoken of benefited primarily the speed of the airship, the engineers continued their unceasing efforts to reduce the weight of the ship's body itself and thus to increase the useful lift. This they accomplished by perfecting the basic mathematical figuration of the ship's framework, utilising in this work the innumerable wartime experiences and lessons with regard to safety and intactness with a minimum of material. The airship was forced to keep pace in this respect with the airplane.



L.Z. 3.

What was the result of all these efforts and improvements?

The military airships at the beginning of the war had, with a size of about 22,000 cbm. (24 tons) and with three motors of a total capacity of 630 h.p., a speed of 18 m.s. (35 kts.); they had, with a weight of 3,000 kilograms (3 tons), an ascending power up to about 2,000 to 2,500 m. (6,500 to 8,200 ft.), according to the temperature conditions.

In 1915 there was created a type of 32,000 cbm., with four motors of altogether 960 h.p. It attained a speed of 25 m.s. (49 kts.) and an ascending power up to 3,000 to 3,200 m. (10,000 to 11,000 ft.), with a weight of 3,000 kg. (3 tons). This type was later made longer and brought up to a size of 36,000 cbm. (36 tons), whereby the ascending power grew by 300 m. (1,000 ft.) without the speed being noticeably reduced.

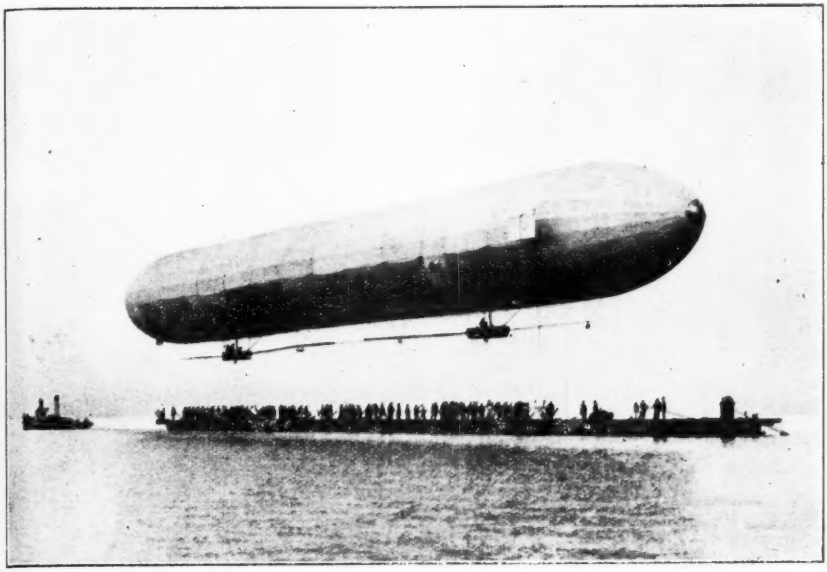
But the rapid development of the airplane made it necessary even in 1916 to bring out a considerably larger and more capable type of airship. It was a vessel of 56,000 cbm. (60 tons) contents with six motors and which had 28.5 m. (55 kts.) speed and an ascending power to about 4,000 m. (13,000 ft.) with 7,000 kg. (7 tons) weight. However, this ship came out at a time when the

phosphorus-igniting missiles for the defence against airships had been introduced, which made the use of this type impossible. A greater ascending power had to be attained. The weight reduction required for this was reached by building out one of the motors and other important alterations in the construction, especially as regards the machine, the engine gondolas and the transference of power. These alterations in construction were also designed to reduce the incidental resistance. The reconstruction showed the really astonishing result that the speed was increased from 28.5 m. to 31 m. (56-60 kts.) per second, and that at the same time the maximum ascending power was gradually increased from 4,000 m. to 5,500 m. (13,000-18,000 ft.) with 7,000 kg. (7 tons) of load. The useful lift had been increased from 45 per cent. to 65 per cent. of the total lift. This type represented in point of construction probably the best attained during the war. An increase of the size to 68,000 cbm. (75 tons) through the addition of two gas compartments, with equal diameter and with a simultaneous increase of

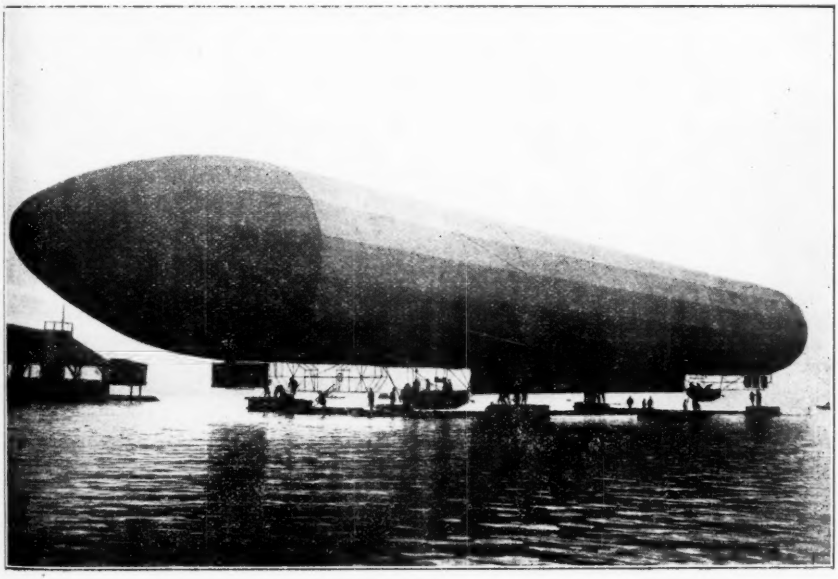
L.Z. 8.

the number of motors to seven, brought no essential improvement. Improvements worth while were not attained until after the war, especially with the Z.R.III., which I shall discuss later. May I first show you a few pictures illustrating the development of the airship before and during the war.

I now come to the latest development in which we tried to utilise our war-time experiences. Only three airships were built after the war—the Bodensee, the Nordstern and Z.R.III. The first two had been designated for traffic between Berlin and Friedrichshafen, but only the Bodensee was actually used in this traffic from the end of August until December, 1919, because these trips had to be discontinued by order of the Ambassadors' Conference. The results of the trial service had been extraordinarily satisfactory. The trips could be carried out in almost any kind of weather, and no mishap occurred unless an emergency landing in the open field during a heavy snowstorm is to be characterised as such—a landing which, by the way, caused no damage to either passengers or



L Z. 1.

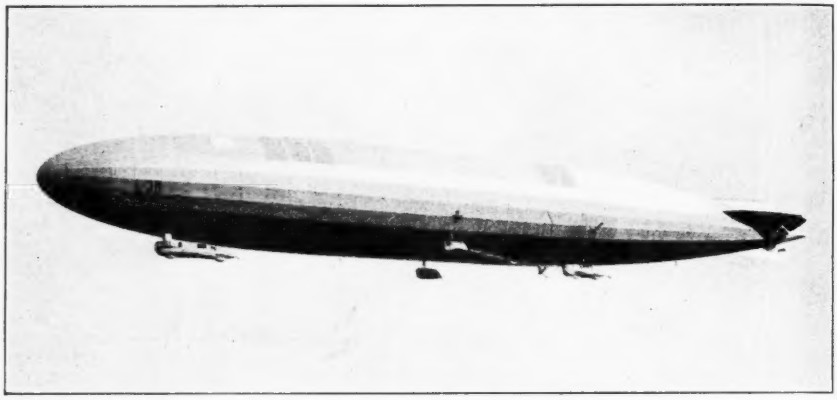


L.Z. 2.

ship. The Bodensee was always occupied to its capacity and it made altogether 103 trips, on which it carried a total of 2,450 passengers.

The Bodensee had a gas capacity of only 20,000 cbm. (21 tons) and was equipped with four engines of 260 h.p. each, which gave the ship a speed of 30.3 m.s. (70 kts.). It had a useful lift of 9,600 kg. (9.4 tons) or 42 per cent. of the total lift. If you compare this with the last passenger airship before the war which, with the same cubic capacity, had a useful lift of only 6,500 kg. (6.4 tons), that is, 30 per cent. of the total lift, and a speed of only 18 m.s. (35 kts.), then you will realise the tremendous headway recorded in the meantime.

It was not possible, of course, in spite of all the progress made in the construction, with such a small ship, to retain the proportion of length to diameter followed up to that time, and at the same time to attain the given carrying capacity. Consequently the proportion of length to diameter had been considerably lessened. The Bodensee was more plump. We should not have dared to



L.Z. 62. L. 30, similar to L. 33.
Gear driven after airscrews still retained.

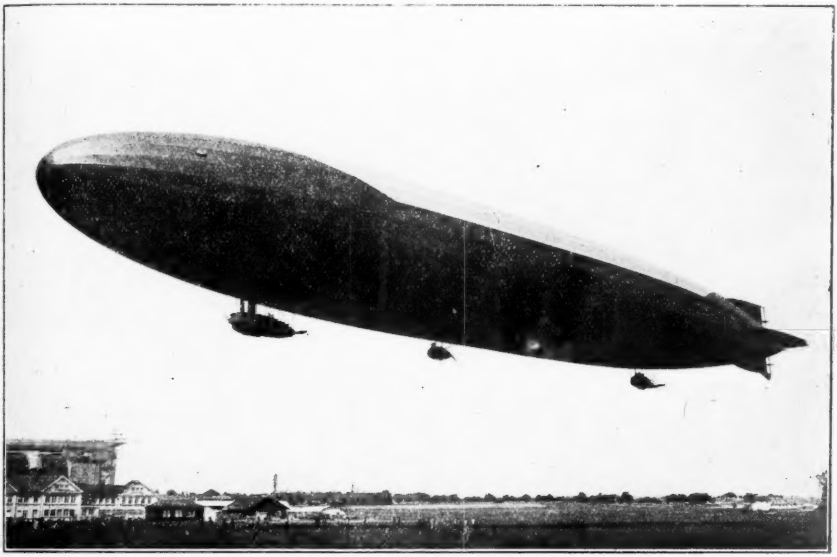
take this step if we had not found in our trials in the wind channel that a ship of such width could be sufficiently stabilised by means of fins of not too large a size, in order to keep it easily in its course. Nevertheless, on the strength of our trials with the Bodensee, we came to the conclusion that it is not advisable to reduce the proportion of length to diameter too much, especially with larger ships. The ships become too unsteady and require too much use of the rudder, which naturally diminishes the speed. Consequently a somewhat less extreme proportion was chosen in building the Z.R.III.

In constructing airships for passenger service there was also the problem of finding the most practical place for the passenger rooms. Technically, the logical solution is, of course, to have these rooms in the ship's centre, in order to keep the proper trimming from being upset by the changing weight consequent to passengers getting on and off. However, the consideration of the fact that this place is more exposed to the vibration and to the noise of the propellers, resulted in the passengers' cabin being placed in front of the ship. We are inclined to believe that this location will be retained in the future, for the comfort in an airship cabin is one of the advantages that the airship has over airplanes.

Now as for the Z.R.III.! The decree of the Ambassadors' Conference had fixed the cubic capacity at 70,000 cbm. (76 tons). The length of the ship is

200 m. (650 ft.), the proportion of diameter to length is about 1 : 7.3; it is somewhat more slender than the Bodensee, but not quite as slender as the 56,000 cbm. (60-ton) type used during the war. It has an outright streamline shape, without cylindrical centrepiece. The course stability of the ship is a very good one, particularly as a result of the excellent efficacy of the fins. Trials in the wind channel had shown that the fins are most efficacious when they are placed at a certain distance from the stern, and our experiences with Z.R.III. confirmed this. As a consequence the size of the fins could be reduced, which, together with their more favourable location, with regard to the strain on the ship, is equally advantageous, probably particularly so for ships fastened to a mooring mast.

In this connection I do not want to fail to say a few things of a general nature about our trials in the wind channel. Our plant in Friedrichshafen, with its 2.90 (9.5 ft.) wind stream diameter and 50 m.s. (164 ft./sec.) velocity, is



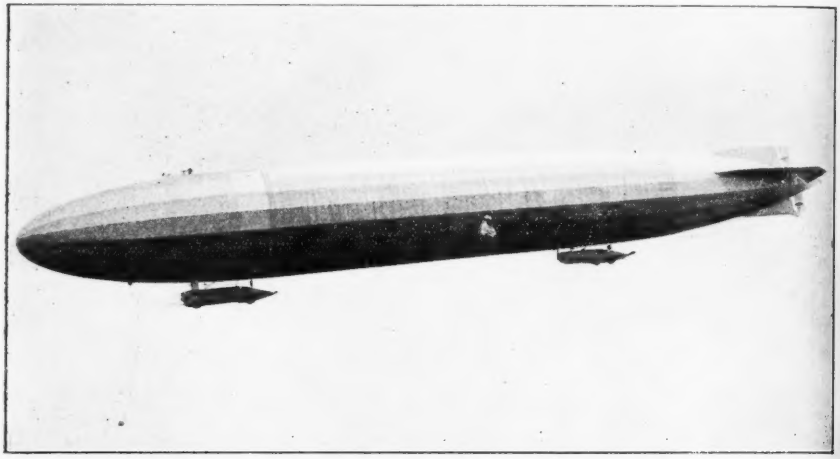
L.Z. 95. L. 48. Doped black for night raids.

probably one of the largest, if not the largest, in existence. It has enabled us to make a thoroughgoing systematic examination of many aerodynamic questions, as for instance, especially with regard to the strain upon the various parts of the ship by the air currents and as regards the most favourable shape of the ship's body and the various extremities like gondolas. The results of these experiments could be, partly at least, utilised in constructing the Z.R.III. In order to transfer the trials made with the model to the ships in their original size, a great number of measurements and experiments with the ship in action are required, of course, and it was a great advantage that we had such measurements and experience at our disposal. Nevertheless a complete transference of the trial results to the ship itself will, unfortunately, scarcely ever be possible. I say, unfortunately, for the importance, for instance, of reducing the ship's resistance will in future be even still more necessary than hitherto. The increase or reduction in the supply of fuel is of the greatest significance for the rentability, especially in long trips, less, perhaps, because it is a factor in determining the costs of operation, than

because the paying load depends upon it. As a matter of fact, the problem of reducing the fuel supply will have to be tackled also with an eye on the engines.

As for the details of the Z.R.III., I shall confine myself to a few characteristic facts, since the ship as a whole is no doubt pretty well known to all those interested. The Z.R.III. shows a novel construction of the corridor, which deviates somewhat from the circle of the cross cut of the ship's body without, however, thereby reverting to the type of outer corridor, in contrast to the inner one used during the last few years. This novelty in construction has two advantages: It heightens the course stability of the ship and it strengthens, for certain reasons, the ship's firmness (intactness). Another novelty in construction is shown by the fins, and which for the first time were built as a self-supporting hollow body stiffened by presswork.

This led to a considerable increase of the firmness of the ship's aft part. Finally, the bow of the Z.R.III. was carefully constructed with a view to permitting its fastening to a mooring mast; this makes the bow considerably stronger



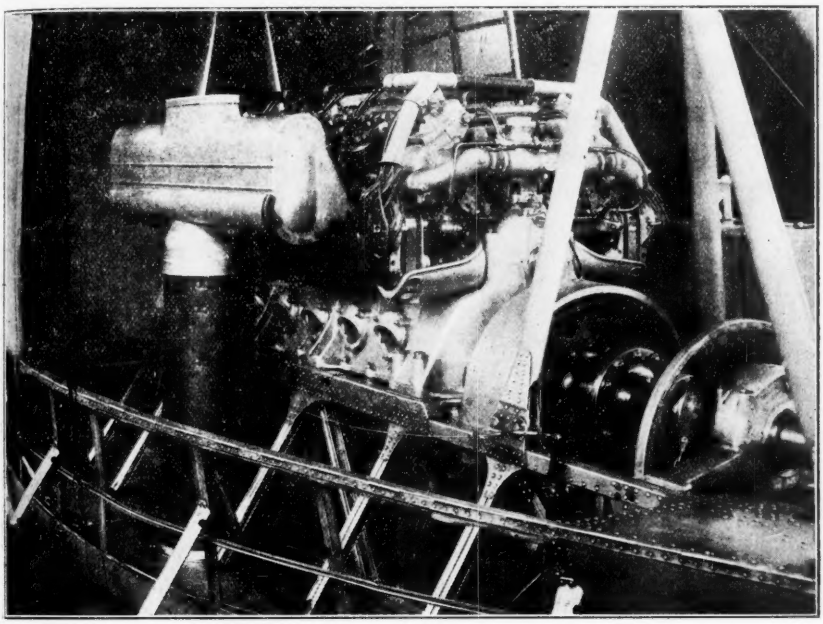
L.Z. 43. L. 12.
Note top gun platform and gear-driven airscrews on gantries abreast after car.

than those of former types. Furthermore, the ship was equipped with a new type of engines, namely, 400 h.p. Maybach motors, which have ball bearings instead of the former bearings, and which can be started and reversed by compressed air.

The speed of the Z.R.III. is 35.3 m.s. (70 kts.), its carrying capacity 46,000 kg. (45 tons), that is, 56 per cent. of the total lift. Although the ship does not in point of size, speed and lift exceed the last wartime types of airship to a considerable degree, it still represents an appreciable measure of progress. For the stability of the ship as a whole has been greatly increased by improved adjustment and dimensioning of the girders, and the coefficient of safety in the individual parts of the ship has been greatly equalised. The vibrations in the framework have been reduced to a minimum, in a manner which is really surprising to everyone who knows the last wartime ships. The reason for this progress is to be found in a thoroughgoing improvement and a more exacting form of the static method of calculation. If we compare our present-day static calculation method with that of 1913 it can be said that we had at that time a somewhat vague theory

of the ship's stability; it gave great leeway to the constructor's individual feelings, it worked with changeable coefficients which had been taken from a comparison with tried and tested ships—in short, it was really quite vague. Nevertheless, it has served in good stead in the transition to the larger types of airships, although often one did not know why a certain construction was still tenable. Thus the development of the airship was during the war, after all, largely empirical, and one often went too far below the theoretically admissible measurements for the sake of reducing weight.

There was not enough time for theoretical investigations, although they were not, of course, entirely neglected. Thus we succeeded in reducing the net weight of the framework from 14,400 kg. (14 tons) with the L.30 to 10,900 kg. (10.5 tons)



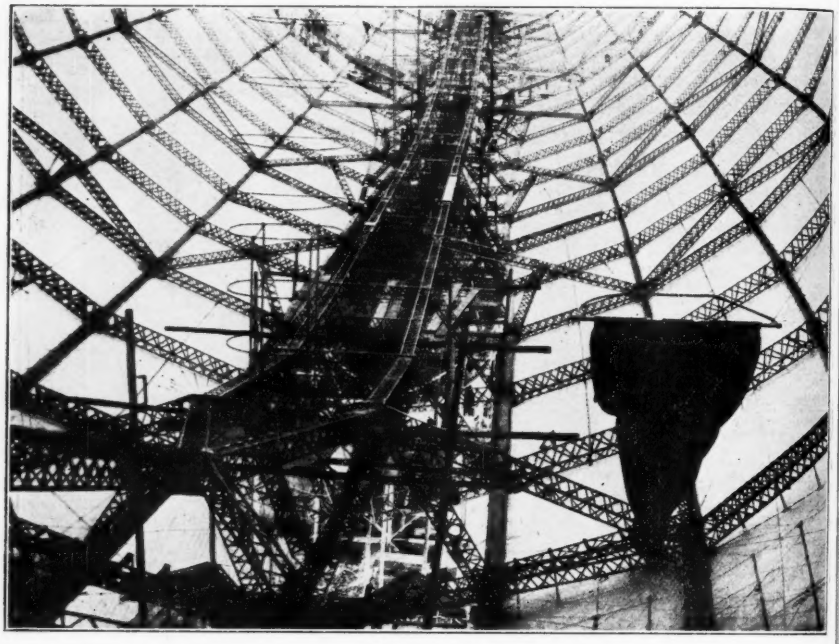
L.Z. 126.

with L.60, a weight reduction of approximately 25 per cent., but the immense material that we had gathered was still awaiting study and utilisation. During the time of the enforced limitation of constructing activity we attempted to place these practical experiences upon a theoretical basis. Presently we learned that the customary scientific doctrine of stability which had been taken over from bridge and machine construction and was governed primarily by the requirements along those particular lines, needed considerable amplification in order to become equal to the peculiarities of airship construction. New points of view were developed with regard to aerodynamic strain—viewpoints with which particularly the process of speed-increase in whirls and other abnormal strains play an important part.

These experiments led, among other things, to the elimination of the cross-wires running through the gasbags, and to a new kind of the transverse wiring, both within the rings and in the fields of framework. Furthermore, they led to a novel construction of the rings as prismatic truss members, which, it is true,

was carried out with the Z.R.III. only in the fins, but which in future will no doubt have to be carried out with all rings.

The theories which we had evolved in this manner were justified in a surprising degree in our practical experiences with the Z.R.III. This is shown in the diagrams of the yielding of the ring cross-wires to exactly the same extent as our theoretical calculation had called for. It is now more easily understood why quite a number of earlier constructions proved tenable in spite of the fact that, under the wartime necessity of reducing weight, the usual admissible measure of saving in material had been exceeded. But in the future, too, we shall hardly be able to avoid this method of going to the utmost limits of utilisa-



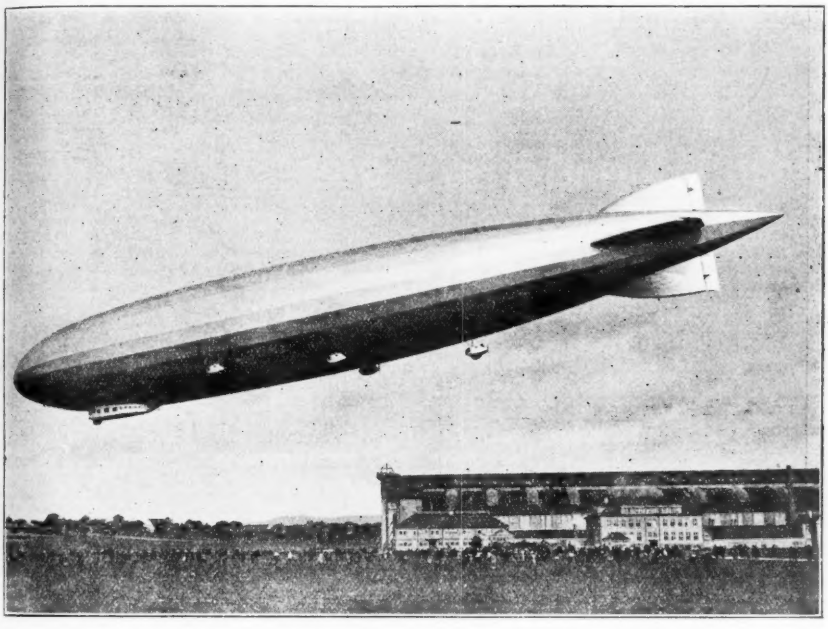
L.Z. 126.

tion of material if the ships are not to become unnecessarily heavy. Moreover, this is quite permissible as long as we have experiences with tried and tested ships to govern us.

It will now be interesting to take up the question as to how airships will be practicably suitable for purposes of traffic, both in the light of their present-day status and of their probable development within the near future, on the basis of a wealth of experiences. It may be fitting, in this connection, to begin by telling how the Z.R.III. stood the test on the trip to America, and what experiences and points of view came into consideration on that voyage. I need not, of course, in this company of experts, combat the view, still widely held by the general public, that storms represent a direct danger to airships in the sense that the lightly built ship might be destroyed in the air or heavily damaged. The layman understands the word "storms" as horizontal air currents of great velocity which, for instance, break masts of ships, tear away sails, uproot trees,

devastate houses and so on. You know that these air currents do not directly menace aircraft which, while aloft, always undergoes only that strain which is caused by its own movements in the air. A storm will never have more effect than delaying or speeding the trip, and it can become directly dangerous only inasmuch as it may delay the voyage beyond the reach of fuel supply. On the other hand, storms are not purely horizontal air currents, but are connected with vertical currents and with turbulent phenomena in the atmosphere, and these air disturbances are certainly something that must demand the full attention of the airship's pilot and that he must combat by proper navigation. These vertical currents are strongest in the frontal side of rain squalls or thunderstorms.

It has been asserted that in such squalls the airship might either be dangerously jerked upward in the ascending air-current on its frontal side and thus



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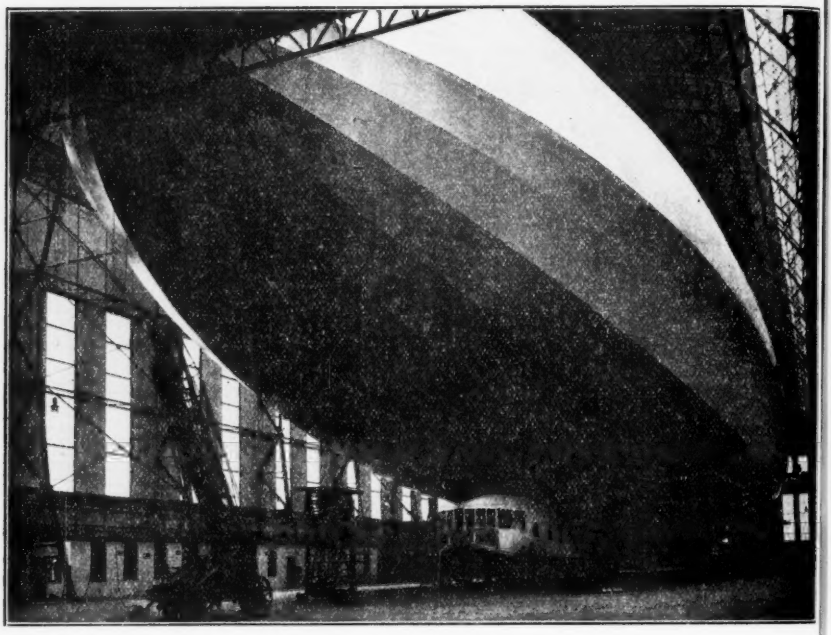
be deflated, or that, in the descending current, in the rear of the squalls, it might be forced to the ground.

Well, I have made more than 2,000 trips and I have often come into the path of such squalls, but it was always easy to keep the airship well in command. True, once I stranded with an airship atop a forest, after the ship had previously been jerked upward and had lost too much gas, but this was an airship whose machinery was no longer intact and which did not have anything like the capabilities of the modern ships. A modern airship is at least as capable in heavy weather as a modern airplane. When we wanted to make the first trial trip with the Z.R.III. it was distinctly to be seen that bad weather was in the offing, but in spite of this I confidently took the air with this still absolutely untried ship; we then rode without difficulty, although going only at half speed, through a very violent squall with heavy rain and hail; an airplane which

attempted to accompany us was forced to land. In order to be equal to all vertical currents in the air the airship must, of course, be maintained in the proper state of balance and must be properly trimmed. If it is too light it will naturally be much sooner jerked upward by a whirl than if it is too heavy, and the violence of the whirl grows at a certain height in the cloud. On the other hand, if the ship is already too heavy it can be more easily pressed downward than if it is too light. Also, an improperly trimmed ship—that is, a ship which is top-heavy or stern-heavy, does not easily remain in the hands of the pilot when it comes into vertical squalls.

In this connection it is noteworthy that a very light or very heavy ship



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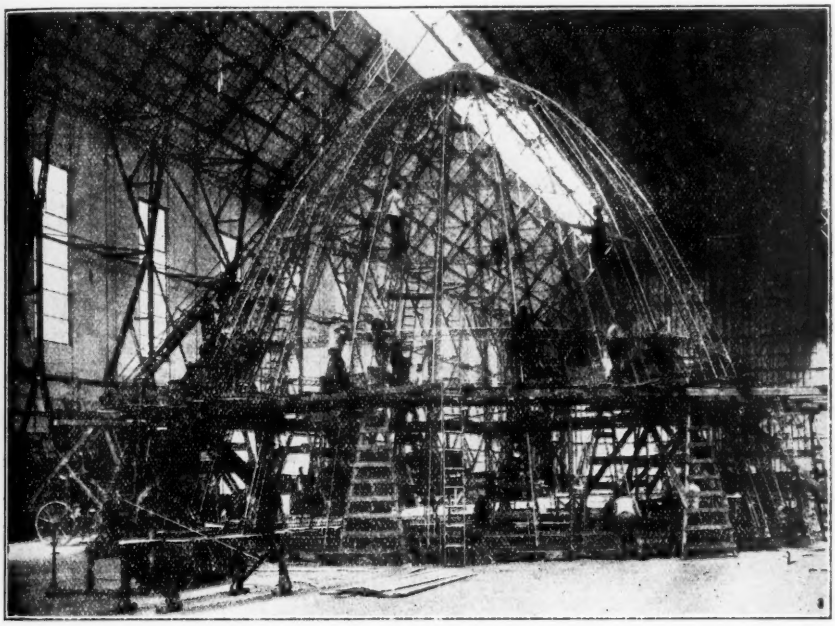
almost undergoes, for certain reasons, a dynamic upsetting of the balance, *i.e.*, it becomes either top-heavy or stern-heavy.

On our trans-Atlantic voyage with the Z.R.III. we were obliged, therefore, constantly to see to it that the great consumption of fuel would not result in an upsetting of the correct trimming, especially since we alternately shut off one of the engines. The pilot requires, even for these reasons, a certain meteorological schooling and "weather nose" in order not to come into difficult weather conditions with a badly weighed or improperly trimmed ship. But it is also necessary to employ some sort of technical means to keep the airship from getting constantly lighter on account of the fuel consumption. The gaining of water ballast from the gas outlet of the engine or the equal consumption of gas and fuel in some other way is not only an economical but also a technical requirement. You know that experiments in both directions are already under way. Personally, I should give preference to the method of gaining water

ballast because the presence of ballast aboard is always a safety factor, especially in landing.

Closely connected with the question of vertical currents is the atmospheric electricity and the question as to whether an airship is menaced by lightning. This question is probably the one which is responsible for most of the scepticism on the part of the public when they think of a proposed regular airship traffic. Squalls with vertical air currents are nearly always accompanied by electrical phenomena, since they are one of the latter's causes. Real thunderstorms differ in this connection from squalls only in degrees. Thus, when one travels in squally weather, therefore, it is easily possible that electrical sparks hit the ship; indeed this is very probable, since the long metallic framework represents a



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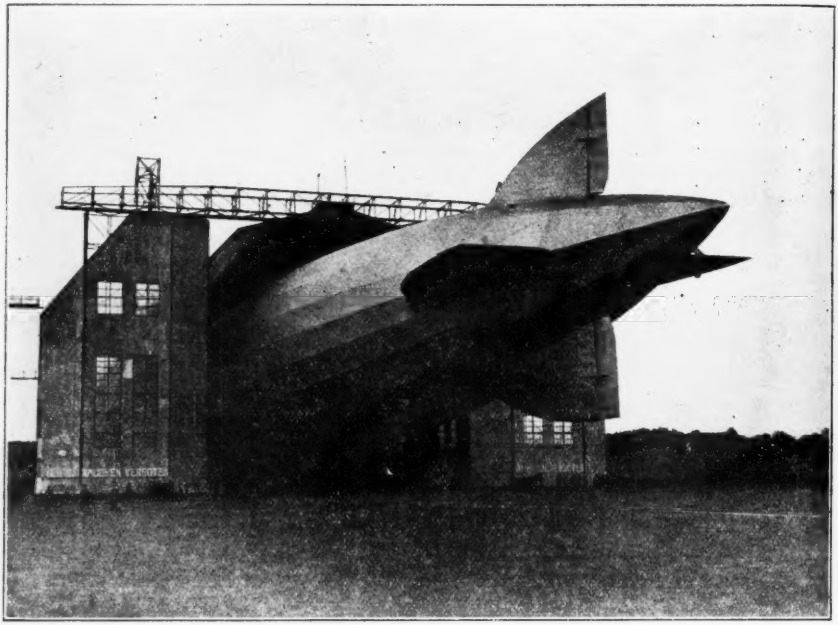
good conductor for the tension equalisation between the various cloud masses. Now, what is the effect of an electric spark or a stroke of lightning upon an airship? Theoretically I have always been convinced, and still am to-day, that lightning is not dangerous; it is caught by the metallic girders located over the gas cells and probably finds its exit mostly somewhere around the stern or by way of the antenne. This has always been my theoretical conviction, though I confess that when I found myself confronted for the first time with the necessity of travelling through a thunderstorm, I was—well, let us say, a bit curious as to how it would work out in practice. But nothing happened to us. Since then it has been established in quite a number of cases that strokes of lightning have hit an airship and have left a small burn-spot at the point of entrance in the outer cover; and in a number of cases, too, the radio station has been damaged by such strokes. However, *one* condition must be given if lightning is to do no harm—the airship must not let out any gas, either through the valves or through deficient gas cells, for otherwise the electric spark may strike an

explosive gas mixture. That is to say, one must have one's ship in good condition and one must not ascend in the *thunderstorm* clouds in order to deflate. This is the reason, too, why the question I discussed before, is of such great importance, namely, whether one can avoid being jerked upward against one's will in whirls and forced thereby to let out gas. We have shown that it can be avoided.

These electrical danger-factors were carefully taken into account in the preparations and the execution of the voyage of the Z.R.III. to America, because we had to anticipate meeting whirls and thunderstorms in the Gulf Stream region. It was seen to, therefore, that the airship had absolutely faultless, gas-tight gas cells. Furthermore, we made sure, by daily trials of the valves



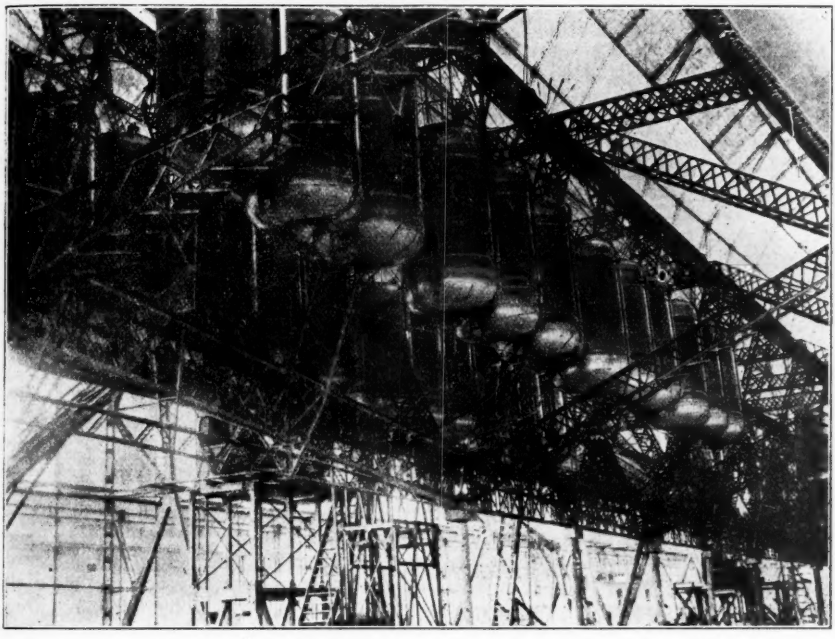
Z.R. 3 leaving Friedrichshaven.

during the last three weeks prior to our departure, that these valves after being pulled, closed up tight with absolute sureness and safety. For with all probability we had to figure that we would be forced to open the valves en route if squalls or thunderstorms should make it inadvisable to go higher and emit gas. During the trip we then utilised the most favourable opportunities, that is, cloudless or lightly clouded sky, in order properly to weigh the ship by ascending and emitting gas before going into heavy cloud masses.

Possibly this procedure which, in view of the significance of the trip itself, we practised with perhaps exaggerated care, may seem to some a bit laborious; but it should be borne in mind that it is not very often absolutely necessary for an airship to ride through thunderstorms or heavy squalls. In most cases the airship can circumvent such atmospheric disturbances. As a matter of fact, however, I am convinced that, in order to remove the last vestige of danger in

connection with the use of hydrogen, we must and will come to a combination of hydrogen and helium. Then we shall emit hydrogen only when it is absolutely safe, and when we can thereby save the expensive helium.

I have discussed the imaginary and actual dangers at considerable length because of their basic importance, though I may add that they did not cause us over much worry or difficulty during the transatlantic trip of the Z.R.III. We were certain that we would be equal to them. I consider the trip which the R.34 made across the Atlantic a few years ago a much bolder feat than was our trip with the much more efficient and more capable Z.R.III. However, we were obliged, in the interest of propaganda for airships, to "put over" our flight in good style, that is, in the briefest possible time, and it is from this viewpoint that I entertained some doubts and concern only with regard to the sufficiency of our



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fuel supply. I calculated that in all probability we could take along about 30 tons of fuel, provided that we limited crew and ballast to a minimum. This amount of fuel would suffice for about 70 operating hours, if we let all five 400 h.p. engines run full speed. Thus we would have covered about 8,700 kilometres (4,650 nautical miles) in wind-stillness. But if one counted upon an average of 6 to 7 m.s. of counter-wind—which is not too high an estimate in the Atlantic in the fall—we would have covered with our 30 tons benzine only about 7,300 kilometres (3,900 n. miles). But the route via the Azores, which we had chosen in view of the advanced season, is 7,500 kilometres (4,000 n. miles). Thus it was clear that we must at any rate travel with reduced speed, that is, with 300 h.p. to each engine instead of 400 h.p. In this manner we could last 96 hours with 30 tons of benzine and cover 8,600 kilometres (4,650 n. miles) with 6 to 7 m.s. (12 to 14 kts.) counter-wind; that is, we could make the 7,500 kilometres

(4,000 n. miles) in approximately eighty-three hours. I was a bit concerned over the question whether the 30 tons of benzine would really bring us to the Atlantic coast. For we had to travel over some medium mountains in France at a height of about 850 m. (2,800 ft.); we had to figure upon possible high temperatures in the noon hour, and, finally, we had to anticipate a considerable cooling of the gas toward evening from 6 to 8 degrees. All this was likely to give our ship an overweight of from 9 to 10 tons towards evening. The dynamic lift of the Z.R.III, it is true, amounts to 8 to 9 tons with 6 degrees elevation and 31 m.s. (60 kts.) speed, but one does not like to take such a heavy ship out into the sea at night. As soon as only one engine failed even temporarily, we would have had to throw off ballast and benzine. Fortunately, thanks to the aluminium coat of the outer cover, the gas-overheat was only two degrees, and thus we had at any rate gained an amount of approximately 1½ tons as against our calculation.

Another concern that might have been entertained, that is, as to whether the engines would stand the test, was removed by the dependability of the new 400 h.p. Maybach motors.

The flight took the following course :—

The ship ascended in Friedrichshafen in dense fog, in a temperature of 10 degrees Celsius (12.5°C.), 400 m. (1,300 ft.) above the sea level, carrying a useful lift of roundly 39 tons, of which 30 tons were benzine, 2 tons oil and 1½ tons water ballast. During the first half of the flight the weather was favourable; over the Azores and over the European Continent there lay a high, and in between a zone with a small disturbance, an outgrowth of a low in the north. Likewise, between Newfoundland and the Bermudas in the Gulf Stream region, there seemed to develop a disturbance of originally indeterminable scope. On our trip across France we had fine weather, with a light south-easterly wind, and made progress with a speed of 105 kilometres per hour (57 kts.). We crossed the summits of the Cote d'Or as low as possible at a height of only 50 m. (160 ft.), and in this way, although over the Cote d'Or we had a temperature of 21 degrees Celsius, we succeeded in reaching the Atlantic coast with a ship that weighed only 5 tons. This load we could well drag through dynamically, especially inasmuch as we reduced it hourly by 310 kg. (680 lbs.) by benzine consumption. Towards seven o'clock in the evening we ran into the afore-mentioned little disturbance; it brought us from 10 to 12 m.s. (20-23 kts.) wind with rain squalls. Under the steep coast of Spain, at Cape Ortegal, the growing wind made itself noticeable in the shape of strong falling gusts which at times caused a more violent yawing and stamping of the ship. An old experience; over land the air turbulence is greater than over the open sea. Toward midnight we had run through the atmospheric disturbance, the wind having changed from south over west to north-west, and now followed a stretch of finest weather until the next evening about ten o'clock; a clear sky and from 2 to 3 m.s. (4 to 6 kts.) of wind, at first north-easterly, then from a southerly direction.

The navigation was governed by drifting measurements by means of pilot bombs, which we dropped, according to necessity, every 2 to 4 hours. Navigation was somewhat difficult and unsteady during the first part of the night, since the wind changed abruptly both in direction and force, and the next morning we stood about 1 degree more to the south than we had assumed; this we established by inquiry from a passing British steamer. The second evening the weather became worse. The wind came with increased velocity from the south-west and toward midnight had reached a strength of from 12 to 14 m.s. (23-27 kts.), so that we made headway only at a rate of 60 to 70 kilometres (32-38 kts.) over the ground. It was obvious that to the north-west of us there lay a considerable depression. But for a long time we could determine nothing accurate about its scope and location, since we were just then along the border of the Gulf Stream, and strong aero-electrical vibrations prevented communication with the radio stations. At last, in the early

hours of the following morning, we had a clear and distinct report from the cruiser Detroit, which was situated 45 west-45 north, that she was having a south-easterly wind 7 force, and also a message from the cruiser Milwaukee, situated about 300 miles to the south-west of the Detroit, that she was having a south-easterly wind force 6 to 7. Now we knew that the centre of the depression must be somewhere between the two cruisers, a bit more to the west, and that it was possible to travel around this centre of the depression, and that we should meet an easterly wind over the Newfoundland banks. We were fully aware that in doing this we should probably run into very heavy weather, but we were certain that we should be able to master it. We therefore took a north-westerly course and already after 6 or 7 hours we ran into a windstill zone, while two hours later —toward one o'clock noon—we got a fresh south-easterly wind with which we steered a westerly course toward Sable Island. For several hours we travelled over the fog of Newfoundland bank, at a height of from 1,500 to 2,000 m. (5,000-6,500 ft.), and the ship was riding quite calmly and steadily, although there was a stiff north-easterly wind. When, at seven o'clock in the evening, we descended in order to determine the direction and velocity of the wind below the fog by means of pilot bombs in the water, we saw that a storm of about 25 m.s. (48 kts.) was blowing over the sea's surface. A few hours previously, on the frontal side of the depression, we had had a temperature of 24 degrees Celsius (30°C.); now, in the rear of the depression we had only 5 degrees Celsius (6°C.) This great contrast in temperature explained the violence of the storm, of course. The air was extraordinarily turbulent over the water, imposing a heavy strain upon the ship. But, with the exception of a single broken cross-wire, the ship suffered no damage whatsoever. After 2 or 3 hours we were clear of the worst weather and now proceeded in a calm, rapid flight to New York, where we arrived at 7 o'clock in the morning.

The trip across the ocean, from the mouth of the Gironde to Sandy Hook, had lasted exactly 70 hours.

I beg leave now to show you a few pictures of the construction and the trip of the Z.R.III. before going over to the last part of my discourse.

The Z.R.III. was built and taken to America by us in order to make propaganda for the airship as a means of traffic. I believe that you, too, are primarily interested in the feasibility of the airship for traffic.

There are three main points to be considered in this respect, namely (1) speed, (2) safety, (3) earning capacity.

(1) As for the first point—speed, airships must attain a considerable saving of time, for the airship is indisputably a more expensive means of traffic than the ocean liner with which it would have to compete, and the higher costs of transportation must be justified by a gain in time. If we take, as an illustration, the voyage between Europe and North America across the Atlantic, it is certain that the airships which nowadays can be built without difficulty for that purpose, can make the trip to America in an average of 60 to 65 hours from coast to coast, as for instance from Cherbourg to Sandy Hook, and the trip from America to Europe in from 45 to 50 hours—assuming a speed of 33 to 34 m.s. (64-66 kts.), which even to-day is easily attainable. Of course, the trips might take as long as 90 hours on certain occasions, and likewise they might take less than 35 hours on other occasions. In case of heavy storms over the North Atlantic the ships will have to make a detour to the southward; as we all know, airship navigation is primarily a meteorological one and only secondarily a nautical one. So the duration of the trip would be reduced to one-half or one-third of that required by ocean steamers.

(2) As regards the safety of airship traffic, I have already discussed this point at length and there is hardly anything to be added to my remarks. Incidentally, I believe that the flight of the Z.R.III. in its second part furnished proof of the airship's power of resistance. But I wish to emphasise particularly that whatever there may be left in the way of danger from fire or lightning must be completely

removed under the further development of the airship. It must not be forgotten that after all we are still in the initial phase of aeronautics, and we must not now interrupt progress, for if we did so we would find great difficulty in resuming the thread of development. We shall be able to render hydrogen entirely harmless by partial use of helium, and we shall be able to substitute crude oil for benzine—if we are seriously determined to go on with airship development! Incidentally, the question of replacing benzine by crude oil is also of the greatest importance for aeroplanes.

The assumption is widely held that landing in stormy weather contains an additional danger factor. I will not deny this categorically, although I do not regard this danger as so great. In case of need an emergency landing place must be sought if the airship cannot remain aloft and wait for the storm to die down. There are times when ocean liners, too, are unable to make port. The delay in docking on account of heavy seas is quite a common occurrence in some of the big sea ports.

In this connection I believe that in the future development we may expect great advantages from the mooring mast. Yet, the mooring mast which is primarily an economic improvement in the methods of landing, does not constitute the simplest or perfect solution of our difficulties. I have long since been of the opinion that the solution lies in placing airship hangars at such locations as meet the chief meteorological conditions, that is, where there is as little wind as possible. Such localities can be found everywhere. The present-day demand is for flying fields as near as possible to the big cities. This may be necessary for airplanes which cover short stretches, but not for airships which have to travel over thousands of kilometres. Ocean liners cannot go directly to Paris or Chicago, nor to London. The automobile, or perhaps the airplane, could undertake the further transport from the airship's landing place.

(3) The third question, that of earning capacity, is perhaps one of the most interesting, but unfortunately at the same time the one concerning which there will be the greatest divergence of views. We have no experiences concerning airship traffic across the sea with big ships. We have tried, however, on the basis of our earlier operating experiences in traffic, to make a calculation as to cost which has been carefully worked out and which, in our opinion, is not too optimistic. It assumes a traffic with three large ships and pre-supposes the presence of large airship hangars on either side of the ocean.

Assuming that during the entire year only 100 trips are made—50 each way—the single voyage would cost approximately 200,000s. (£st. 10,000) including all writing-off, insurance, etc. As against this cost, there would be the revenue from an average of 15 tons of paying load on each trip. These 15 tons of useful lift could be distributed as follows: 5 tons for 30 passengers with a given weight for free luggage, food, etc. Each passenger would pay £125, making a total of 75,000s. (£st. 3,750); 5 tons for letter-mail, each 20 grams paying 9d., that is approximately triple rate, which does not seem too high, considering the saving in time. That makes a total for mails of approximately 167,000s. (£st. 8,350). The last 5 tons would be for baggage transportation, parcels post, newspapers and such like, all of which would pay the same rate as passengers, namely, 15s. per kilogram. This would bring an additional 75,000s. (£st. 3,750). Thus the grand total of revenue would be £st. 15,850, as against £st. 10,000 expenses on each trip. I might add that £st. 125 per passenger seems a very low price. As soon as the feeling of safety has taken hold of the general public there will be a wild scramble for the 30 seats, and the price per seat can be considerably increased. Furthermore, I believe that the traffic in urgent parcels post will be so great that the 5 tons of lift reserved for that purpose would not suffice.

The revenue-surplus of each trip, that is, £st. 5,850, would make £st. 585,000 for the 100 trips during the year. The total investment capital required for the traffic as outlined amounts to £st. 1,750,000—if one puts the figure very high. The interest would therefore amount to 34 per cent.

I might point out that these calculations do not include the possible and probable saving that will accrue from the use of mooring masts, nor do they include incidental revenues growing out of paid visits to hangars, leases, advertising contracts, etc.—all of which may bring in tidy additional sums of money.

I believe, therefore—and this sums up my remarks—that the question of the feasibility of airship traffic should be viewed most particularly from the standpoint of good business, and I am glad to find that there is an impetus in that direction here in England. But I do not want to fail to emphasise also that airship traffic is a matter of international collaboration and I take pleasure in expressing the hope, therefore, that the airship may become a means of bringing the nations of the world closer together in harmonious co-operation.

Discussion

The Chairman said that the meeting had listened to a very clear and a very interesting account of the development of the airship, and the voyage of the Z.R.III. Three main impressions had been left upon his mind. These were, first, what fun the voyage must have been; secondly, how solid the construction of the ship looked; and thirdly, how well the development of the airship bore out the theory that the more efficient an engineering construction was, the more beautiful it was. Dr. Eckener had flattered those present by referring to them as a body of experts. He himself feared, however, that there were very few experts in this country; most of them were only experts enough to have an open mind, but the technical development of the airship would surely make them believe in Dr. Eckener's concluding statement, that the question of the feasibility of airship traffic must now be viewed more particularly from the point of view of good business. Sir Alan Anderson, who had given a great deal of thought to this question, was present, and he (the Chairman) felt certain that those present would wish to hear his views. Therefore, he asked Sir Alan if he would be good enough to open the discussion.

Sir Alan Anderson said he felt sure that those present would first wish to thank Dr. Eckener for his wonderfully interesting story of the twenty-five years or more during which his Company had been working. It was an extraordinary story of courage, and faith, and vision, and now it seemed that gradually, after all these years, their dreams were beginning to come true. He hoped that, as Dr. Eckener had said, the success of airships would be the means of bringing the whole world more closely together. It did not seem long ago since the Zeppelins had visited this country in quite a different sense, but at the present time we welcomed Dr. Eckener. Germany and this country had been good enemies, and he hoped they would be good friends. It was very necessary to realise that this job was one in which we had all to join together. The Zeppelin Co. had solved many problems, but there were a great many yet to be solved, and it was not a question which one nation or one group of men could monopolise. They had all to work together. Had it not been for that terrible disaster in which we had lost General Maitland and those other noble fellows who had worked with him, we should have been in better shape. Now, however, we were apparently going ahead, or were about to go ahead fairly rapidly, and he very much hoped that our Government was in the closest possible touch with the Zeppelin Co., and that on both sides there was the will to work together, because, directly the commercial use of these airships was started, the difficulties with regard to frontiers would arise, and we should find these horrid frontiers stretching up into the air and stopping all that we wanted to do. Therefore, we must get together, and if these great ships which would stretch out over long distances in the air were used properly, it seemed to him that they would become one of the greatest influences for civilising the world. After all, what had held us back in Europe more than anything else were frontiers and Customs,

and if these ships were flying over all the frontiers, we should have a freer commerce. That was the thought that had impressed him most when listening to this lecture. Of course, the war had not yet been obliterated, and there were such things as peace treaties and difficulties about building these ships in Germany, but he could not believe it was right to perpetuate those feelings any more than was absolutely necessary. The sooner we got rid of the feelings engendered by the war, the better, and we should then go ahead. What had we got to hope from airships? We were a great marine nation, as also was Germany, and we had much to hope for in bringing the whole of our Dominions on the other side of the world within a six days' journey of this country. Who could say what that meant? He was a steamship owner, and some steamship owners looked upon the airship as a competitor and dangerous. Of course, if airship development came all of a sudden, it would render the ocean ships out of date, but he personally did not think that ship owners need be afraid of airships. His impression was that, if we could bring Australia within a six days' journey of this country, the traffic would increase so enormously that the ocean ship could well spare traffic to the air and still be better off than before. He would not like the airship, however, to be spoon-fed and subsidised by the Governments, and did not like the idea of airship fares being a third or a quarter of what they ought to be. (Laughter.) Dr. Eckener had fallen into that trap. He had said that £125 was a very low fare, but still he had included it in his paper. Dr. Eckener had said that the airship was indisputably a more expensive means of traffic than the ocean liner, but Sir Alan did not know whether he was right in that. Also, with great respect, he did not believe Dr. Eckener knew. We did not know yet how many voyages the airship would make. Those problems remained to be solved, but, assuming a ship made a reasonable number of voyages, and did not burn or drown its passengers, the saving of time was so immense that, in his view, it outweighed the extra expense to people in a hurry. After all, cost was not merely a matter of £-s.-d. It had to be measured also in time and in convenience, and if we could get these ships doing regularly and safely what they did at present occasionally, and what the "Bodensee" appeared to do safely and regularly, we should find that the cost was completely outweighed by the saving of time. He might instance himself as an example. He had been a ship owner trading with Australia all his life, but twenty-two years had passed since he was last in Australia, where all his interests were connected. He had been busy looking after his business here, but everyone who had a business such as his, and could get to Australia in six days instead of six weeks, would go out every year; it would pay him hand over fist. It would be nothing to pay £500 for such a chance. Dr. Eckener, when speaking of heavy oil, did not seem to think it was yet quite certain that it would be used. Ocean-going ships were getting on very fast with the use of heavy oil engines, and he hoped that perhaps the air engines would progress equally fast. With regard to navigation, Dr. Eckener had said that there were times when ocean liners were unable to make port. General Maitland had taken him (Sir Alan) for several trips in airships, and his impression was that when our airmen had as much experience as our seamen, the handling of these ships in ordinary weather would prove to be a comparatively simple problem as compared with the ocean ship. An airship had always sea room above her, and when an ocean ship had sea room on one side, her difficulties had scarcely begun. Ocean ships could only come into the Port of London at slack tide, and it had to be a fine day, and the navigators came in with their hearts in their mouths all the time. In conclusion, Sir Alan said he was sure all those present would wish to thank Dr. Eckener for his very interesting lecture. The only sympathy he felt inclined to give Dr. Eckener was that, according to the photographer, many of his ships, and some of his distinguished persons, seemed to lack initial stability. (Laughter.)

Major-General Sir SEFTON BRANCKER said he could tell Dr. Eckener at once that the Government of this country was determined to go on with the development of airships for commercial purposes and for Imperial communications. With regard to the question of costs, he believed some optimists would swing the opposite way from that indicated by Sir Alan Anderson, and say that they could reduce the fare to £50, but in Government Departments £-s.-d. was everything, and time and convenience took a second place. They had to be optimistic about the £-s.-d. He was not an expert, but was thirsting for information, and would venture to ask one or two questions. In the first place, he had been very pleased to hear Dr. Eckener's optimistic outlook with regard to lightning. Only quite recently, for the first time in his experience, an aeroplane had been struck by lightning whilst flying, with alarming, though not serious, results. The wireless instrument and aerial were fused, and the whole machine became magnetised, but no other damage was done. Dr. Eckener had alluded to the combination of helium and hydrogen, and it would be interesting to know if he intended that the helium should be inside the outer cover, but surrounding the gasbags, or whether his idea was a double set of bags, part of them filled with helium and part with hydrogen. Again, if Dr. Eckener had a free hand at the present time to build a ship for commercial purposes, and had to face the problems such as we had got, *i.e.*, communicating with India and Australia, what size of ship, and what speed, would he suggest? We had a problem before us which he did not think the German Zeppelins ever had to face, and that was the operation of ships in the tropics, where they would have a very strong sun, and often very cold nights, and tremendous hailstorms, in which literally the hailstones were the size of pigeon's eggs. He had known people killed by hailstones in India. The only example of an airship working in that part of the world was the adventurous voyage of one of the German Zeppelins towards German East Africa. It was in the winter, and the ship had ventured over very difficult country. The ship did not reach German East Africa, and he had never heard the reason why she turned home. Perhaps Dr. Eckener could tell them. Dr. Eckener had mentioned the necessity for meteorological training for the captain of a ship, and he would like to ask whether Dr. Eckener considered it worth while to have a meteorological officer as a permanent member of the crew of a ship—a man who had been thoroughly trained in meteorology from his youth up. It was the irony of fate, and a fate which fell to the lot of many inventors, that Count Zeppelin had died just as his great invention was coming into its real and its best use, *i.e.*, commercial air traffic throughout the world. He had always felt grateful to Count Zeppelin; during the war he had felt grateful to him, because his invention had done more than anything else to educate the British public regarding the value of aviation and its possibilities. (Laughter.) From now onwards, Count Zeppelin's invention would do more towards binding the British Empire together than anything else. Finally, General Brancker thanked Dr. Eckener for the extraordinary amount of good he had done by his successful voyage to America. It had brought many wavering critics to the side of the airship, and the fact that the Z.R.III. had accomplished the voyage without any trouble or alarm had done a tremendous amount of good all round. For that he thanked Dr. Eckener very heartily.

Major SCOTT said it had been extremely interesting to listen to a pilot of such experience as Dr. Eckener, who had made over 2,000 flights, and it was particularly interesting to note that his experience agreed in almost every respect with what had been found in this country. With regard to strong winds and storms, there was practically no danger arising from vertical currents, and, in his 2,000 flights, Dr. Eckener had always found that he got through even the worst of the squalls. He agreed with Dr. Eckener that the pilot of an airship must have meteorological training, and, even if a meteorological officer were carried, the pilot must still have considerable knowledge of meteorology, because

otherwise he was entirely in the hands of the meteorological officer. Long-distance flying depended more upon meteorology than upon actual navigation. He also agreed with Dr. Eckener with regard to the need for maintaining the balance of the airship when encountering storms. As to the statement by Dr. Eckener that he considered the flight of the R.34 to be a bolder flight than that of the Z.R.III., Major Scott agreed that the Z.R.III. was a much fitter ship for the Atlantic flight than was the R.34, but it must not be forgotten that the flight of the Z.R.III. was a considerably longer flight, and he considered that the flight of the Z.R.III. was a much greater flight and much more important than that of the R.34, and had done much more for aviation. As to the statement that two degrees of superheat was found during the Atlantic flight of the Z.R.III., he asked whether that was the average or the maximum; if it were not the maximum, he would like to know what the maximum superheating was. With regard to navigation, it seemed from the paper that Dr. Eckener had depended almost entirely upon dead reckoning, and he would like to know whether he had made any celestial observations. Also, had directional wireless been used to any extent during the flight? In conclusion, Major Scott thanked Dr. Eckener, on behalf of himself as well as every pilot in this country, for having given them all the information contained in the paper.

Admiral FULLER, after expressing his pleasure at having been able to attend the lecture, said he had met Dr. Eckener before, and had found him very interesting. Dr. Eckener's prowess with regard to airships was, to his mind, perfectly marvellous. Sir Alan Anderson had said a good deal about how the airship could help with regard to sea work, and therefore he himself did not propose to discuss that again, but would content himself with expressing his thanks to Dr. Eckener.

Colonel RICHMOND added his tribute of thanks to Dr. Eckener for his kindness in delivering the lecture, and to the Zeppelin Co. for their work. He quite agreed with Major-General Sir Sefton Brancker that this generation owed Count Zeppelin a great debt, and that future generations would owe him a still greater debt. Sir Alan Anderson had sounded the keynote when he had referred to the courage and the faith and the wisdom that was necessary to initiate this great idea, and he was glad to say that there were certainly signs that that courage, faith and wisdom was growing in this country, although we were a good way behind in the race. With regard to the question of superheating, Colonel Richmond said we had worked out a theory in this country, as the result of which it was the opinion that the superheating should be less in large ships than in small ones, and he would like to know whether Dr. Eckener's experience supported that. With regard to the shape of ships, Dr. Eckener had referred to fineness ratio, and appeared to hold the opinion that, judging between the "Bodensee," which had a fineness ratio of about 6½, and the Z.R.III., which had a fineness ratio of 7.3, the limit had been reached somewhere between those two. He would very much like to know if the excellent aerodynamic work which had been done in the wind channel at Friedrichshafen bore out that contention in any way, because the aerodynamical work done in this country had led to a distinctly opposite view, *i.e.*, that certainly the limit had not been reached in ratios as low as 6.5. As to water recovery, which he quite agreed was a desirable step forward, there was perhaps an additional reason, which had not been raised, as to why this was a sounder thing to do than to consume hydrogen, and that was that on long journeys it would minimise the difficulty of providing adequate gas supplies at intermediate stopping places, which was a matter of considerable importance from the point of view of capital cost. Dr. Eckener would no doubt forgive him if he drew attention to two points in the construction of the Z.R.III. which he considered it was only fair to say were anticipated by constructors in this country in the ill-fated R.38, and all credit was due to them for these

particular innovations. One was the question of the shape of the cross section, in which the ship had a point at the bottom and two long straight sides meeting at that point, although it was not actually an external keel. That was incorporated in the R.38. The second point was the use of diamond trusses in the transverse frames. With regard to the mooring mast, Dr. Eckener had expressed the opinion that, whilst the mooring mast represented a great step forward, the solution lay in placing airship hangars in such locations that met the chief meteorological conditions, *i.e.*, where there was as little wind as possible. But why not place the mooring mast in the same position? Undoubtedly our airships, for commercial purposes, would have to be sufficiently robust to need their hangars only on rare occasions, or on occasions only as frequent as those on which a steamship needed to be "dry-docked." In again expressing his thanks to Dr. Eckener, he pointed out with what great interest we in this country viewed the doings of the Zeppelin Company, and how he hoped that, both technically and from the point of view of commerce, the airship would be a vehicle whereby we should all be drawn more closely together.

REPLY TO DISCUSSION BY DR. ECKENER.

Arrangement for combination of helium with hydrogen for inflation of gas-carrying airships.—The idea is that only hydrogen shall be consumed while practically the same margin of safety is attained as if the ship was inflated with helium only. For this purpose large gas cells of the usual shape are provided to be filled with helium and inside of each of these cells there is situated a separate smaller cell to be inflated with hydrogen. The lower specific weight of the hydrogen may cause that the inner cell will float within the surrounding helium, if its balloon cover is chosen adequately in quality. Or a combination gas cell may be provided allowing a somewhat cylindrical inner space for hydrogen and an outer jacket space for helium, both cells having common end-walls in which the gas valves may be situated. There are also a good many other ways of carrying into practice this principle. The main thing is that the relation between the helium and hydrogen capacities should be chosen so that under normal conditions only hydrogen is discharged by the gas valves, and the helium valves are to come in action only in case of emergency. Of course, the double walls and valves of the gas cells will cause an additional weight, but it does not appear impossible that the lower weight of hydrogen will make good for that, so that at least the same disposable lift and safety may be attained as if the ship was inflated with helium only, but the advantage gained is that the less expensive hydrogen only is consumed and has to be reinflated.

We have worked out several designs with respect to this arrangement which we expect to answer the purpose. Of course, as soon as helium will be available in greater quantities and at a cheaper price, this makeshift way of construction will be abandoned again. Its importance, however, may last as long as the consumption of hydrogen in the ship's motors is under consideration.

Size of ships.—We think that for the beginning—until we have experiences with very big ships—ships of the size of four to five million cubic feet capacity inflated with hydrogen would do for the service to India on which way you intend to arrange an intermediate stop in Egypt. Of course, this does not mean that experience may prove it advisable to continue the service with bigger ships. The speed should not be too low; we consider 80 miles cruising speed and a maximum speed of 90 miles good limits. Certainly all this may vary according to special purposes and with regard to special investigations in this question which may have led you to some other conclusions. A valuable answer to this question would need closer investigation.

Meteorologist on board ship?—It depends very much on the pilot in command of the ship, who under all circumstances should be a good meteorologist. I personally would not think that I needed a meteorological expert on board my ship, but of course I would not object to having one in my crew. The main thing is that this meteorologist should also have training in operation of ships, because the experience in the air will add a lot to his more or less theoretical knowledge, and it will lead him to a different comprehension of what kind of weather service is needed in aeronautics.

Superheat in gasbags.—Two to $2\frac{1}{2}$ degrees centigrade superheat in the gasbags was the maximum due to the varnish and ventilation. Possibly superheat is higher in small ships than in bigger ones, but I would not venture to give a definite answer in this respect. Further experiments will have to prove this.

Observations on board.—Celestial observations were not made on the American trip, but only directional wireless was made use of.

Ratio of length to diameter.—We have compiled a good many data on this question, but we do not consider it solved yet and are still going on experimenting. However, in practical operation we had best results with ships of not too large a diameter. There are different aspects to it, taking into consideration the various tasks for which a ship may be destined. I would say that it is most likely that for the different types of ships also different ratios will prove best.

Site of mooring masts.—I assume that I was misunderstood. The idea is that the site for sheds should be chosen only with regard to their best meteorological situation, while mooring masts might be erected in places where traffic conditions would make it most desirable. This does not mean that mooring masts might not be on the same field with sheds if meteorological and traffic conditions allow this.

The CHAIRMAN, in asking the meeting to accord Dr. Eckener a hearty vote of thanks for his paper, mentioned that he had been nominated as a German Presidential candidate, but had felt that that also was not in his department, and that he would prefer to devote himself to his present great work. They would all feel very sympathetic towards him, and would hope that he would get over his political difficulties in the same manner as he had got over his technical difficulties. If he did that, it was certain that he would go a very long way towards bringing his country and others into closer co-operation.

The vote of thanks was accorded with acclamation, and the meeting closed.

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